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CONTENTS

(Vol. XXV, Part II)

(June 1955)

Original articles

Reviews

ORIGINAL ARTICLES

DEVELOPMENT STUDIES IN CROP PLANTS

I. INFLUENCE OF NITROGEN, PHOSPHATE, POTASH AND CALCIUM, ALONE AND IN COMBINATION, ON WHEAT

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(Received for publication on 28 March 1952)
(With Plate V and one text-figure)

THE growth of the plant is the joint result of the influence of various growth factors ; a change in the intensity of any of the growth factors may manifest its influence on the plant development in different ways. Each fertilizer has a certain specific effect on plant. It alters its habit of growth and composition. Nitrogenous fertilizers increase the size of leaf, thereby augmenting its efficiency as a carbohydrate producer, and thus tend to produce certain changes, only some of which are desirable. Potassic fertilizers without increasing the size of leaves increase their assimilatory activity. Used in conjunction with nitrogenous fertilizers potassic manures maintain plants in normal condition by promoting the formation of carbohydrates to balance the extra nitrogen compounds.

Waterman and Ruhnke [1925] observed that in the absence of nitrogen, plants do not grow normally, while an abundance of nitrogen produces luxuriant vegetative growth, delays maturity and makes the crops, particularly cereals, susceptible to lodging. Richardson Fricke [Quoted from Cook and Baten, 1925] working on sandy soils found that heads of the wheat grown in fertilized field were longer than those of the wheat grown in unfertilized field. Richardson and Gurney [1933] showed that ammonium sulphate resulted in vigorous tillering. Verma [1935] reported that phosphate influences the tiller number and that increasing doses cause further increase in tillering. Similar conclusions have been drawn by Gregory [1937]. Reitz and Myers [1944] noted an increase in average height due to phosphate application. The increase ranged from a fraction of an inch to three inches. The influence of potassic fertilizers on the number of tillers was studied by Mathur [1933] on barley. He found that increased doses of potash reduced the number of tillers when the supply of nitrogen was kept constant. Verma [1935] observed that potash decreased the tiller number in barley in the presence of high doses of phosphate. It was found to balance the effect of nitrogen and phosphate when the latter was supplied in larger amounts. Calcium forms an essential component of plant tissues. The action of lime is partly physical and partly chemical, setting free the dominant plant food. It also corrects soil reaction. Lee [1946] summarising the effects of lime on plant growth observed that the importance of lime to plant growth is more as a liberator of plant nutrients from the soil complex than as nutrient to the plant. Harcourt [1905] observed that the plots on which oats lodged contained least lime and most nitrogen. Murphy [1930] reported that in various mixtures applied at 300 lb. per acre phosphate caused more lodging than others. On the other hand, Reitz and Myers [1944] observed that there was no consistent

effect of phosphate on the lodging of cereal crops. Kostling [1930] noted that increased spacing per plant produced greater stooling and stronger culms, more resistant to lodging, and better development of kernels. Walton and Morris [1931] considered that lodging may be avoided to some extent partly through quality of seed and partly through handling of soil. In seeding tests, plants from the higher rates or from smaller seeds often lodged while those from lower rates or larger seeds remained erect. They recommended that stiff straw varieties may be used. The most helpful practice appeared to be that tending to reduce temporarily the available fertility, particularly nitrates, by straw mulching. Growther, *et al.*, [1937] observed that lodging had only slight effect in reducing the size of the grains. It proved to be closely correlated with total nitrogen of the whole plant.

Murphy [1945] reported that protein content increased as the amount of nitrogen in the soil was increased. With the introduction of phosphate in the fertilizer whether singly or with nitrogen, the protein content decreased. Knowels and Watkins [1931] while experimenting on the assimilation of nutrients in wheat found that the percentage of plant nutrients in wheat is highest in the earlier stages and goes on decreasing with the age of the plant. The crop had been analysed at the stages of (i) tillering, (ii) flowering and (iii) complete ripeness. Murphy reported that the percentage of protein in both grain and flour was reduced by the application of phosphate, and increased by the application of nitrogenous fertilizers, the potassic fertilizer having little effect. High dose of phosphate with limited or no nitrogen resulted in definite nitrogen deficiency in the plant. Protein content was influenced most by the available nitrogen supply at the boot stage of plant growth.

Layout and Treatments

Effect of nitrogen, phosphate, potash and lime on wheat, applied each at three levels, alone and in combination, was studied at the Indian Agricultural Research Institute farm. The experiment was conducted in a $(3)^4$ factorial design with two replications arranged in a quasilatin square as described by Yates [1937]. The following set of second order inter-actions had been partially confounded between rows and columns :

Rows	ABC(X)	ABD(Z)
	ACD(W)	BCD(Y)
Column	ABC(Y)	ABD(W)
	ACD(X)	BCD(Y)

The actual layout can be seen in Plate I, while the index of treatment combinations is given in Table I.

The variety under test was C.518. The fertilizers applied to add the required amounts of nitrogen, phosphate, potash and calcium were ammonium sulphate, superphosphate (triple), potassium sulphate and lime. As lime could not be mixed with ammonium sulphate, it was applied about a month before seeding. The rest

3^4 N, P, K, Ca, EXPERIMENT

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LODGING OF WHEAT C. 518.

N

PLOT No.	N	P	K	Ca.
66, 115	0	0	0	0
37, 92			80	
32, 143			160	
63, 150			0	5
76, 121			80	
53, 135			160	
24, 84			0	10
2, 158			80	
16, 100			160	
80, 126	20		0	
54, 132			80	
58, 145			160	
7, 154			0	
15, 102			80	
20, 86			160	
41, 98			0	10
30, 142			80	
64, 110			160	
11, 104	40		0	
25, 82			80	
6, 156			160	
28, 137			0	5
68, 116			80	
39, 97			160	
49, 130			0	10
62, 153			80	
81, 123			160	
52, 127	0	80	0	
60, 147			80	
74, 122			160	
14, 107			0	
21, 88			80	
1, 155			160	
35, 144			0	10
72, 114			80	
40, 94			160	
19, 83	20		0	
5, 161			80	
12, 106			160	
67, 112			0	5
44, 99			80	
36, 141			160	
65, 149			0	10
79, 118			80	
51, 129			160	
45, 96	40		0	
31, 139			80	
71, 117			160	
78, 130			0	5
47, 131			80	
61, 145			160	
3, 160			0	10
10, 101			80	
23, 89			160	
4, 157	0	160	0	
17, 108			80	
27, 87			160	
38, 95			0	5
34, 136			80	
69, 111			160	
73, 119			0	
50, 134			80	
57, 151			160	
33, 138	20		0	
65, 113			80	
43, 91			160	
48, 133			0	
55, 146			80	
77, 125			160	
18, 105			0	
22, 85			80	
8, 162			160	
59, 152	40		0	
75, 124			80	
46, 128			160	
26, 90			0	
9, 159			80	
13, 103			160	
70, 109			0	
42, 90			80	
29, 140			160	

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TABLE I

Index of treatment combinations

1st digit	Combination of N and P		2nd digit	Combination of K and Ca	
1	0 lb.	0 lb.	1	0 lb.	0 lb.
2	20 ,,	0 ,,	2	80 ,,	0 ,,
3	40 ,,	0 ,,	3	160 ,,	0 ,,
4	0 ,,	80 ,,	4	0 ,,	5 ,,
5	20 ,,	80 ,,	5	80 ,,	5 ,,
6	40 ,,	80 ,,	6	160 ,,	5 ,,
7	0 ,,	160 ,,	7	0 ,,	10 ,,
8	20 ,,	160 ,,	8	80 ,,	10 ,,
9	40 ,,	160 ,,	9	160 ,,	10 ,,

of the fertilizers were mixed with the soil before seeding by broadcasting in the respective plots two or three days before sowing. Development studies were recorded on the crop.

CHARACTERS STUDIED AND SAMPLING TECHNIQUE

Observations on the following characters were recorded :

1. Germination
2. Number of shoots per plant
3. Cumulative growth in height of the main shoot
4. Number of functioning leaves on the main shoot
5. Length of the matured ear
6. Number of grains per ear
7. Weight of grain per ear
8. Effect of lodging on main shoot height, length of ear and number of grains per ear
9. Uptake of nitrogen at various stages of growth as influenced by various combinations of nitrogen and phosphate

Since it was not possible to study all the individual plants of the experimental plots at the successive stages of growth, 'sampling unit system' was adopted and the samples were selected for detailed observations as follows :

(*a*) *Germination*

The germination was recorded by counting all the plants falling in 8 ft. row length taking 2 ft. at four different places in each plot. The crop had been sown with

a seed drill. These observations were recorded in both the replications of the experiment.

(*b*) *Number of shoots per plant, number of functioning leaves and the height of the main shoot*

Four plants in each of the plots of the first replication were labelled for recording observations on these characters. The first observation was recorded after 26 days of sowing the crop and subsequent ones after every 10 or 15 days till the crop matured in 110 days.

(*c*) *Average weight of grain per earhead*

Number of ears from 2 ft. length, taking one foot at two different places, harvested from the unlodged portion of the crop were counted, thrashed and weighed for each plot in both the replications. The mean weight per ear was calculated by dividing the total grain weight by the number of ears. Similar calculations were made for the lodged portions in plots where lodging occurred during the season.

(*d*) *Length of the ear and number of grains per earhead*

The plants labelled for studies mentioned in (*b*) above were used to determine the ear length and the number of grains per earhead.

(*e*) *Percentage of nitrogen uptake*

Twenty selected plants taken at random from each of the plots receiving nitrogen and phosphate and their combinations (*i.e.* treatments 11, 21, 31, 41, 51, 61, 71, 81 and 91 respectively) were removed for chemical analysis at the following stages: (i) End of formative period, *i.e.* end of the tiller formation period and the beginning of the grand growth period ; (ii) Pre-flowering period, *i.e.* at the appearance of the flag leaf and the emergence of the ear but before setting of grain and (iii) Maturation stage, *i.e.* on the ripening of the crop when grain and straw were separately analysed for nitrogen content.

(*f*) *Effect of fertilizers on lodging and the extent of loss*

The extent of lodged area was mapped on a graph paper after setting a *munj*-rope net having meshes one foot square (specially prepared for the purpose). The net was spread in each plot and the lodged area was marked on the graph. From the map thus prepared the extent of lodged area was calculated with the aid of a planimeter. The mean extent of the loss was calculated in the manner described in (*c*) above. The ratio between the produce from the lodged and unlodged crop was obtained by dividing the total produce from the lodged area by that from the unlodged area. Since nitrogen effect indicated significant influence on lodging, its effect per lb. of nitrogen per acre was worked out. This was based on the difference between the weight of grains from lodged and unlodged crop into the mean area lodged for the various treatments.

Experimental Results

The results of the investigations carried out are briefly reported as under:

(*a*) *Germination*

Though there appeared to be a wide variation in the number of plants per foot row, yet the statistical analysis of the results revealed that the fertilization did not show any influence on the germination of the seed.

Table II

Mean number of plants per foot drill row

Particulars of fertilizer irrespective of other treatments	Levels of fertilizers		
	0	1	2
1. Nitrogen doses	11·09	11·01	11·26
2. Phosphate doses	10·78	11·05	11·53
3. Potash doses	11·36	10·98	10·92
4. Lime doses	11·28	10·96	11·11

General mean = 11·12 ± 0·30
Difference amongst the treatments not significant

Similar findings have been reported by Richardson and Gurney [1933] and Russell and Watson [1940]. On estimating the number of seeds sown and the number of plants obtained per row foot it was noticed that only 50 per cent of the seeds sown could emerge as seedlings under field conditions though the seed was capable of giving 95 per cent germination.

(*b*) *Number of shoots*

In the formative stage, after germination, the plants tend to form new shoots rather than show rapid growth in the height of the plants. Tillering commenced 17 days after seeding but the period when on an average each plant possessed one tiller (another shoot) was about 26 days as can be seen from the data given in Table III.

It is evident from Table III that maximum number of shoots was reached after 66 days of sowing indicating that the effective shoot emergence period was about 50 days in the life cycle of the crop. Later on though a few new tillers were observed yet the rate of mortality was heavy causing a definite decline at each successive observation, till on an average two shoots were left per plant at harvest.

Various fertilizers and their levels also began to exhibit their influence on the tillering process from the commencement of the formative period of the crop as is evident from the data given in Table IV. This table gives results showing effect of nitrogen, phosphate, potash and lime as percentage increase over the no-fertilizer treatment to indicate the trend of increased or decreased number of shoots during the life cycle of the crop. Obviously, nitrogen and phosphate had a marked positive

TABLE III

Mean number of shoots (main shoot & tillers) per plant. Effect of main factors irrespective of the treatment combinations

Serial No.	No. of days after sowing	Nitrogen levels			Phosphate levels			Potash levels			Lime levels			General mean
		0	1	2	0	1	2	0	1	2	0	1	2	
1	26	1·72	1·93	1·94	1·90	1·90	1·64	1·98	1·83	1·77	1·89	1·89	1·88	1·86
2	36	3·15	3·48	3·54	2·95	3·59	3·62	3·38	3·37	3·42	3·48	3·32	3·36	3·38
3	46	3·67	3·20	4·01	3·44	4·23	4·20	4·05	3·83	3·99	4·07	3·83	3·97	3·96
4	56	4·28	4·91	4·43	3·87	4·90	4·84	4·74	4·28	4·59	4·55	4·39	4·67	4·53
5	66	4·32	4·99	4·39	3·93	4·91	4·81	4·81	4·30	4·58	4·58	4·41	4·71	4·56
6	81	3·86	4·66	4·11	3·70	4·42	4·51	4·50	3·88	4·25	4·10	4·04	4·42	4·21
7	96	2·10	2·38	2·29	2·14	2·32	2·05	2·40	2·17	2·20	2·17	2·20	2·40	2·23
8	110	..	..	..	..	..	..	2·08	1·90	2·05	2·00	2·01	2·02	2·01

S.Em for the main effects (8th observation) = ± 0·093
C.D. at 5 per cent = 0·28

TABLE IV

Mean effect of nitrogen, phosphate, potash and lime irrespective of other treatment combinations on shoots, as percentage increase over control at each successive observation

Particulars		Days after sowing							
		26	36	46	56	66	81	96	110
1. Per cent increase over N_0	N_1	12·2	10·5	14·5	14·7	15·5	20·7	13·3	19·6
	N_2	12·7	12·4	9·3	3·5	1·6	6·5	9·1	17·9
2. Per cent increase over P_0	P_1	..	21·7	23·0	26·6	24·7	19·5	8·4	4·1
	P_2	2·1	22·7	22·1	25·1	22·4	21·9	7·5	5·1
3. Per cent increase over K_0	K_1	—7·6	—0·3	—5·4	—9·7	—10·6	—23·8	—9·6	—8·7
	K_2	—10·6	+1·2	—1·5	—3·2	—4·8	—5·5	—8·3	—1·4
4. Per cent increase over Ca_0	Ca_1	—4·2	—4·6	—5·9	—3·5	—3·7	—1·5	1·4	0·5
	Ca_1	—0·5	—3·4	—2·5	+2·7	2·9	7·8	10·6	1·0

response as compared to their respective controls, while potassium and calcium exhibited depressing effect almost throughout the crop-growing season. The increasing doses of nitrogen encouraged shoot emergence in the beginning but later on single dose (20 lb. nitrogen per acre) showed better response than the double dose. In the case of phosphate, the differences in its single and double doses were never more than three per cent, indicating that additional quantity did not show corresponding effect. Although the percentage increase was higher up to 66 days yet as the mortality commenced, nitrogen treatments manifested greater shoot survival than the phosphate treatments. Potash instead of increasing the shoot emergence actually depressed it. The depressing influence of potash with double dose (160 lb. K_2O/acre) was greater than the single dose at the commencement but at harvest single dose exhibited more depression in shoot emergence of the crop. Calcium showed the least influence on the number of shoots. Although, to start with, the influence was of the negative character, at harvest it showed a slight increase. Shoot emergence at harvest is important from the point of view of grain yield of wheat crop. Therefore, the analysis of final data recorded on 110th day after sowing (8th observation) was carried out. This indicated significant differences in nitrogen treatments (Table III). The differences are shown as under :

$$\overline{N_1 \quad N_2 \quad N_0}$$

The shoot number in the application of 20 and 40 lb. nitrogen doses increased significantly over no-nitrogen treatment. Phosphates application also increased shoot number over control but the differences were not significant. Application of potash had adverse effect. Lime dressings made slight difference in number of shoots at final stages.

(*c*) *Cumulative growth in height*

The differences in shoot heights as measured up to the auricle of the highest fully matured leaf were not well-marked either due to various fertilizers or under their varying levels as is evident from the data given in Table V.

TABLE V

Mean cumulative growth in height of the main shoot in inches, effect of the main factors irrespective of the treatment combinations

No.	Days after sowing	Nitrogen levels			Phosphate levels			Potash levels			Lime levels		
		0	1	2	0	1	2	0	1	2	0	1	2
1	36	2·09	2·16	2·30	1·98	2·28	2·29	2·28	2·17	2·10	2·20	2·16	2·21
2	46	3·60	3·82	4·03	3·40	3·80	4·20	3·85	3·95	3·60	3·80	3·70	3·90
3	56	6·70	7·00	7·60	6·60	7·30	7·40	7·30	7·12	6·79	7·08	6·87	7·37
4	66	9·78	10·00	10·27	9·58	10·27	10·20	10·23	10·10	9·73	10·19	9·83	10·03
5	81	20·68	20·57	20·60	20·09	20·99	20·76	21·10	20·41	20·42	20·85	20·33	20·67
6	96	32·84	33·25	32·20	32·60	32·69	33·00	32·97	32·33	32·90	33·25	32·68	32·35
7	110	35·60	36·10	34·70	35·30	35·50	35·50	35·50	34·99	35·80	35·80	35·40	35·10
8	130	35·60	36·10	34·70	35·50	35·50	35·50	35·50	34·99	35·50	35·80	35·40	35·10
Harvest height up to ear end		41·50	42·90	41·20	41·70	41·90	42·00	42·10	41·20	42·40	42·40	41·70	41·50

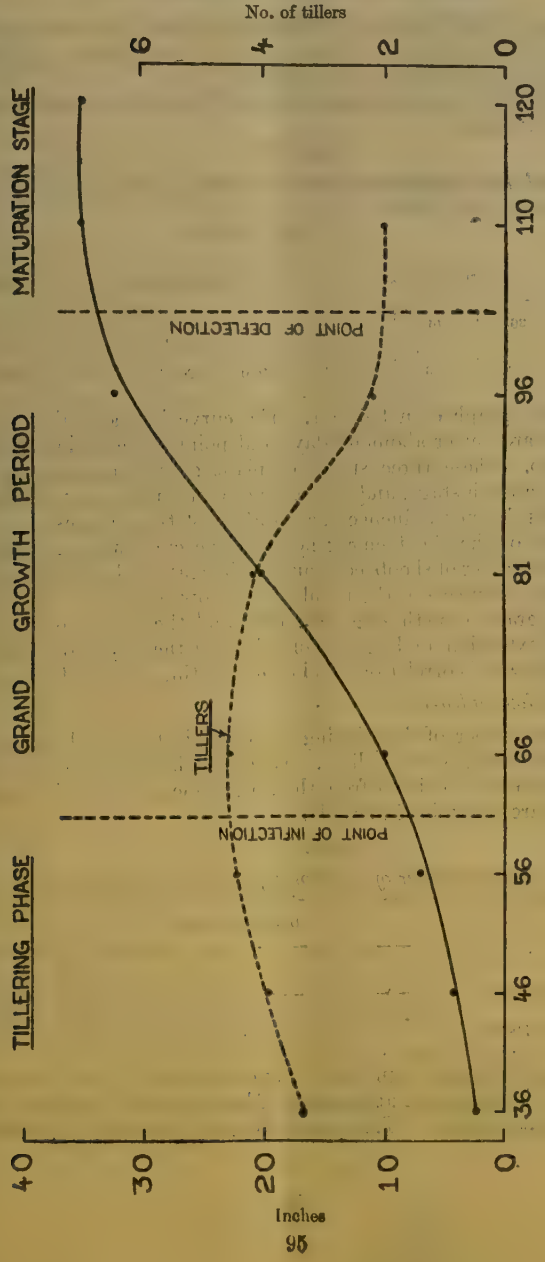

FIG. 1. Mean cumulative growth in height and tillers

Except for the small effect of nitrogen and phosphate levels up to 66 days, the trends in cumulative growth were fairly uniform in all the treatments. At harvest, the differences in accumulated growth were very small.

The data in Table VI gives the mean growth in height at successive stages of the crop during its life cycle.

TABLE VI

General mean cumulative growth in height of main shoot

Main shoot	Days after sowing							
	Formative stage			Grand growth period			Maturation stage	
	36	46	56	66	81	96	110	120
Height in inches	2·18	3·83	7·11	10·0	20·64	32·76	35·45	35·45

The data have been graphed in figure 1. The curve indicates that the point of inflection was indicated after about 66 days and point of deflection after 100 days of sowing the crop. These three stages of plant growth namely : (i) formative, (ii) boom or grand growth stage, and (iii) stage of maturation were well-marked and different treatments did not influence the duration of these stages.

Combined study of the shoot emergence and the cumulative growth in height data indicated that number of shoots continued to increase up to 66th day ; thereafter, there was continuous decrease in the number of shoots per plant. The decline was arrested when the grand growth stage was over and the crop entered its stage of maturity, so that extension in height took place at the expense of shoots. This indicates a strong growth ' correlation ' and compensating effect in the wheat plant.

(d) Number of functioning leaves

Analysis of the number of functioning leaves indicated small difference either due to nitrogen, phosphate, potash or lime. There was, however, progressive increase in the number of leaves as is evident from the general mean values of the functioning leaves. The data are given in Table VII.

TABLE VII

Mean number of functioning leaves on the main shoot

Particulars	Days after sowing						
	36	46	56	66	81	96	110
No. of leaves	2·34	2·65	3·37	3·70	4·18	4·66	4·10
Per cent increase over the preceding number	..	13·2	27·2	9·8	13·1	11·5	—12·0

The maximum increase in the number of leaves occurred in the period up to 56 days. Thereafter, the successive appearance of leaves slowed down and they began to dry up after about 100 days. This period coincides with that of grain formation in the crop.

(e) *Length of ear*

The differences in the length of ears were small. The variation amongst the treatments was of the order of 3·5 to 7 per cent.

TABLE VIII

Mean length of ears in inches due to main factors irrespective of the treatment combinations

Fertilizer	Levels of fertilization			Remarks
	0	1	2	
Nitrogen	2·64	2·74	2·72	Differences not significant amongst the treatments
Phosphate	2·70	2·70	2·70	
Potash	2·80	2·60	2·70	
Lime	2·70	2·70	2·70	

(f) *Number of grains per ear*

It appears that the effect of increasing doses of nitrogen and other nutrients was more marked on the number of grains than on the length of the ear. The statistical analysis showed that significant differences were brought about by nitrogen and potash applications while phosphate and calcium exhibited very small increase in the number of grains. The data are summarised in Table IX.

TABLE IX

Mean number of grains per ear (irrespective of the treatment combination) due to the main factors

Nutrient applied	Levels of fertilization			Remarks Differences at P=0·05
	0	1	2	
Nitrogen	29·9	33·9	33·4	N_1 N_2 N_0
Phosphate	32·1	32·4	32·6	Not sig.
Potash	34·8	29·9	32·4	K_0 K_1 K_2
Lime	32·0	32·1	33·0	

General mean = 32·3 ± 1·14
C.D. at 5 per cent = 3·41

Russell [1939] observed that increased yield due to nitrogen may be obtained by an increase in either the number of grains per earhead or the number of ears per plot or the weight of grain. In the present investigations, the trend of the increase in the number of grains per ear was in the order N_1, N_2 and N_0, the same as was found in tillering. In potash, the single dose significantly lowered the number of grains as compared to the control, the double dose also showing similar but less depression in this entity.

(*g*) *Effect of fertilizers on lodging*

The figures of the lodged area in relation to the various fertilizer treatments are given in Table X.

TABLE X

Mean lodged area per plot in sq. ft. Mean effect of main factors irrespective of treatment combinations (Total area per plot—581 sq. ft.)

Nutrient applied	Levels of fertilization			Significant differences at 5 per cent
	0	1	2	
Nitrogen	125·87	205·4	273·98	N_2 N_1 N_0
Phosphate	179·4	223·4	202·5	Not sig.
Potash	202·9	195·4	206·9	Not sig.
Calcium	199·1	192·9	213·3	Not sig.

General mean = 201·75 ± 35·43
C.D. 5 per cent = 71·43 C.D. at 1 per cent = 94·67

It is evident from the data that it was the presence or absence of nitrogen that brought about the difference in the extent of lodging in the crop. The increased application of nitrogen resulted in increased lodging of the crop. It appears, excess of nitrogen produced an abundance of vegetative growth with relatively weaker culms [Miller, 1940] and due to the stress of violent wind the crop was ' laid ' down. The phosphate levels showed some effect on lodging of crop but the differences were not significant. Potassium and calcium showed very slight influence on lodging and it appears, they neither caused an increase nor prevented the lodging of the crop.

Differences in the length of ear, number of grains per ear and mean length of shoot were examined for the lodged and unlodged crop. These observations were recorded in all those plots in which lodging had occurred (Fig. 1). The data of these observations are recorded in Table XI.

TABLE XI

Shoot height, length of ear and number of grains per ear for lodged and unlodged plants

Plot No.	Nutrients per acre in lb.				Unlodged		Lodged		No. of grains per ear	Shoot height (inches)
	N	P	K	Ca	Length of ear (inches)	No. of grains per ear	Shoot height (inches)	Length of ear (inches)		
74	0	80	160	0	3·0	37	45·5	3·0	22	36·0
..	..	..	..	..	2·5	27	45·5	2·0	10	32·0
101	40	80	80	10	3·4	59	45·0	2·8	27	37·5
					2·8	38	43·5	2·5	38	34·0

TABLE XI—(*contd.*)

Shoot height, length of ear and number of grains per ear for lodged and unlodged plant

Plot No.	Nutrients per acre in lb.				Unlodged		Lodged		No. of grains per ear	Shoot height (inches)
	N	P	K	Ca	Length of ear (inches)	No. of grains per ear	Shoot height (inches)	Length of ear (inches)		
102	20	0	80	5	2·8	35	45·5	2·5	25	35·5
					2·7	31	40·0	2·5	29	29·0
103	40	160	160	5	2·9	34	45·5	2·2	27	38·0
					2·3	20	41·0	2·6	34	39·5
104	40	0	0	0	2·3	26	45·5	2·7	32	35·5
					2·7	33	40·8	2·2	30	38·0
105	20	160	0	10	2·2	23	40·5	2·8	34	39·0
					2·7	22	43·5	2·8	34	40·5
106	20	80	160	10	2·8	41	47·0	2·0	20	35·0
					2·8	27	48·0	2·8	35	45·0
108	0	160	80	0	2·5	33	44·0	2·8	37	44·0
					2·8	37	39·5	2·5	33	35·5
109	40	160	0	10	2·5	30	40·5	2·6	36	42·0
					3·0	29	46·0	2·0	28	30·0
117	40	80	160	10	3·3	51	42·0	3·0	44	46·0
					2·9	32	39·2	2·3	9	38·0
139	40	80	80	0	2·3	23	45·5	2·5	28	38·0
					2·6	30	43·0	2·5	11	40·0
142	20	0	80	10	2·4	29	46·0	2·7	35	38·0
					2·5	24	47·0	2·7	30	35·0
				Total	64·7	771	1049·5	61·0	688	901·0
				Mean	2·7	32·1	43·6	2·5	28·7	37·7

The mean heights of the unlodged and lodged shoots were 43·6 and 37·5 in. respectively thus showing a reduction of 14 per cent. This difference was significant at 1 per cent level of significance. The mean lengths of the ears of the unlodged and lodged were 2·7 and 2·5 in., the difference being significant at P=0·05. The number of grains in the two cases were 32·1 and 28·7 respectively. This indicated a loss of 10·5 per cent. The difference is significant at 5 per cent level of significance.

Besides, the mean weight of grain per lodged and unlodged ear was also worked out by dividing the total grain yield by the number of ears from which that yield had been obtained. The mean weight per lodged and unlodged ear was found to be 0·75 and 1·06 gm. respectively. The loss of 26 per cent due to lodging was very

highly significant at 1 per cent level of significance. The degree of loss in the grain weight appears to be the highest of all the losses resulting from the lodging of the crop.

The mean weight per thousand kernels was 37·4 and 41·0 gm. respectively for the lodged and unlodged crop, indicating that the size of the kernel was also reduced due to early lodging. This difference was significant at 5 per cent level of significance. The average bushel weight also revealed a decrease, as it was 63·1 lb. for the lodged and 63·6 lb. for the unlodged crop. The decrease being less than 1 per cent, the data was not likely to show significant effect.

The loss in yield was heavier in the case of grain, it being about 63 per cent while in straw it was about 36 per cent. This reduction in yield was brought about by a decrease in almost all the measurable characters contributing to the total dry matter production or grain yield of the crop. Multiplying the loss in yield computed from the loss in grain weight by the extent of lodging in various treatments, measured in terms of area of the lodged field, and then dividing by the nitrogen dose unit, the loss in weight per pound of nitrogen per acre was worked out (the detailed procedure will be described in the succeeding paper). Each pound of nitrogen caused about 4·5 lb. reduction in grain yield as compared to control.

(*h*) *Uptake of nitrogen*

In Table XII are given the data of nitrogen uptake by the crop at various stages of its growth.

TABLE XII

Mean nitrogen concentration at different stages of growth of the crop

Stage I End of formative period (68 days after sowing)	Stage II Pre-flowering stage (92 days after sowing)	Stage III Complete ripeness (154 days after sowing)	
Whole plant 2·67	Whole plant 1·32	Grain 1·53	Straw 0·33

The percentage nitrogen concentration showed a decline as the crop advanced in age. Thus, the mean nitrogen concentration was 2·67 per cent at the end of the formative period, but was reduced to 1·32 per cent at the stage of pre-flowering. However, at maturity, the major portion of the nutrients was transferred for the grain formation and, therefore, the nitrogen concentration in grain increased to 1·53 per cent at the cost of straw which had only 0·33 per cent nitrogen content.

Besides the age of the crop, the amount of nitrogen and phosphate applied also significantly (at P=0·05) influenced the per cent nitrogen uptake at all stages of crop growth except in the case of straw where the differences were not significant. The double dose of nitrogen in the absence of phosphate brought about a significantly higher concentration of nitrogen over either control or a single dressing of nitrogen. In the presence of phosphate the nitrogen doses did not show any significant difference amongst themselves (Table XIII).

TABLE XIII

Mean nitrogen per cent concentration in wheat plant at the end of the formative period

Phosphate treatments	Nitrogen treatments			Mean
	N_0	N_1	N_2	
P_0	2·17	2·14	4·13	2·81
P_1	3·44	3·01	2·88	3·11
P_2	2·12	1·92	2·09	2·07
Mean	2·61	2·36	3·03	
	Main effects		Interactions	
S.E.	±0·17		±0·30	
C. D. at 5 per cent level	0·55		0·95	
	N_2 N_0	N_1	P_1 P_0	P_2

In the absence of nitrogen, the single dressing of phosphate gave a significantly higher concentration of nitrogen over either control or double dressing, the difference between the latter two being not significant. With the single dose of nitrogen, significantly higher concentration of nitrogen was obtained when single dose of phosphate was used than when double dose of phosphate was used. Single or double dressing of phosphate significantly reduced the nitrogen concentration when applied with double dressing of nitrogen. The data for the nitrogen concentration at the pre-flowering stage are summarised in Table XIV.

TABLE XIV

Mean per cent nitrogen content at pre-flowering stage

Phosphate treatments	Nitrogen treatments			Mean
	N_0	N_1	N_2	
P_0	1·02	1·51	1·62	1·38
P_1	1·32	1·55	1·34	1·40
P_2	1·19	1·00	1·30	1·16
Mean	1·18	1·36	1·42	1·32
	Main effects		Interactions	
S. Em	±0·060		±0·11	
C. D. at 5 per cent	0·20		0·34	

Higher concentration was manifested by double dose of nitrogen, single dose of phosphate and no phosphate in combination with nitrogen dose treatments respectively. Single dose of nitrogen treatment also exhibited increased concentration of nitrogen in the plant over no nitrogen treatment.

The difference with double dose of N was not so marked as at the formative period of the crop. Single dose of nitrogen in combination with double dose of phosphate continued to maintain a low level of nitrogen concentration. On the contrary, in the absence of phosphate or its single dose in combinatoin with single or double dose of nitrogen appeared to maintain higher nitrogen concentration in the plant at the pre-flowering stage of the crop.

At maturity, the concentration of nitrogen in grain and straw was as shown in Table XV.

TABLE XV

Mean per cent nitrogen content in grain and straw at maturity

Phosphate levels	N_0		N_1		N_2		Mean	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
P_0	1·44	0·40	1·59	0·41	1·77	0·39	1·60	0·40
P_1	1·28	0·35	1·68	0·41	1·81	0·28	1·59	0·35
P_2	1·39	0·25	1·43	0·24	1·41	0·25	1·41	0·25
Mean	1·37	0·35	1·57	0·35	1·67	0·31	1·53	0·33

S. Em. (Grain) $= \pm 0{\cdot}501$

S.E. (Straw) $= \pm 0{\cdot}058$

C.D. at 5 per cent Main effects (Grain) $= 0{\cdot}16$

C.D. at 5 per cent Interactions (Grain) $= 0{\cdot}28$

The differences in grain values for the main effects and the interactions were significant at 5 per cent level of significance.

$\overline{N_2 \quad N_1} \qquad N_0 \qquad \overline{P_0 \quad P_1} \qquad P_2$

The differences in straw values were not significant for the main effects and interactions. A general survey of the values indicates that a similar trend in the concentration of nitrogen is observed as at the pre-flowering and formative stages of growth of the crop. Single and double dose of nitrogen alone or in combination with single dose of phosphate showed greater concentration of nitrogen in the grain. Combination with double dose of phosphate, on the other hand, resulted in significantly lowering the per cent concentration of nitrogen in the grain. Straw did not indicate any special differences in this respect.

Summary

Effects of various levels of nitrogen, phosphate, potash and lime and their combinations were studied on the various characters of wheat plant. Differences were noted in respect of germination, progress of tillering, number of functioning leaves on the main shoot, mean ear length, average number of grains and mean weight of grain per ear. Besides, the effect of nitrogen and phosphate on the uptake of nitrogen by the crop was studied. The crop lodged late in February and the influence of fertilizers on lodging and ultimate yield was investigated. The conclusions are as under:

1. The various nutrients and their combinations did not influence the germination of the crop.

2. Tillering commenced 17 days after germination. Maximum shoot number was observed after 66 days of sowing. Later heavy mortality of shoots was noted. This coincided with the point of inflection of the curve of growth in height when the plants had entered their grand growth period. Fertilizers manifested their influence. Nitrogen encouraged tillering and helped in greater survival of shoots at harvest. Thus harvest number of shoots for the nitrogen treatments were higher by 20 per cent over no nitrogen treatment. Application of phosphate showed an increase of over 4 per cent at harvest. By potash application, there occurred a decrease of about 4 per cent in the shoot number compared to control. Lime had slight effect on shoot emergence.

3. Cumulative growth in height was less affected by fertilization, the differences at harvest being small.

4. The differences in functioning leaves were least marked due to the effect of differential fertilization to the crop.

5. Nitrogen and potash significantly induced variations in number of grains per ear in spite of the variations in ear being small. The former brought about an increase and the latter, decrease, in the number of grains per ear.

6. Effect of nitrogen was particularly marked on the lodging of the crop. The reduction in yield was brought about in all the measurable characters contributing to the yield of grain. Thus each pound of nitrogen reduced the grain yield by 4·5 lb. per acre. The loss thus sustained was 63 per cent in grain and 36 per cent in the straw yield.

7. The per cent concentration of nitrogen declined as the crop advanced in age. The increasing doses of nitrogen (20 and 40 lb.), either alone or in combination with single dose of phosphate, caused a greater concentration of nitrogen than the presence of double dose of phosphate, which throughout showed a lower concentration. Mean effects of nitrogen and phosphate levels were significant.

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STUDIES ON SALINE SOILS OF DELHI STATE

III. *DABAR* (LOW LYING) AREAS

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In parts I and II of this series, [Raychaudhuri and Sankaram, 1952; Raychaudhuri and Tripathi 1952] the nature of the saline soils in the *khadar* areas of Delhi State has been studied. In this article, a study has been made of the saline soils in the *dabar* or the low-lying area of the State.

According to the climatic classification, the soils of Delhi State come under the broad group of semiarid soils. The percentage of organic matter is low and the soils are mostly alluvial or aolian in nature, the texture being sandy loam to sandy clay loam.

A typical profile in the alkaline alluvium of the Punjab consists of three well-marked layers as given by Puri [1949], namely, an upper highly alkaline layer which is compact and impervious; the second layer which is of medium alkalinity containing calcium carbonate nodules (calcareous layer) and the third layer which has lower alkalinity and higher permeability than the preceding layers. Below the third layer usually sand occurs.

The morphological features of several solonetz-like soils of Bombay-Deccan have been described by Basu [1937] to serve as a basis of soil classification. The nature of representative saline soils of Madras have similarly been indicated by Ramiah [1941].

The CaO : MgO ratio is of special importance because it governs the properties of the soil and affects the nutrition of plants. Gedroiz [1931] reported that oats and mustard plants made practically no growth in soil saturated with magnesium. He found that addition of calcium carbonate partly overcame the toxicity of Mg saturated soils.

N. I. Usov [1937], while studying the effect of absorbed Mg on saline properties of soil at Sarotove, stated that when absorbed Ca : Mg is greater than 3, the physical properties of the soil are modified by the calcium content. When Ca : Mg is less than 2, the soil becomes heavier, its structure coarser and fissuring takes place on drying. Gauch and Wadleigh [1944] made comparison of effects of concentrations of calcium chloride, sodium chloride and magnesium chloride on bean plants grown in solution cultures. They concluded that the effects of calcium chloride and sodium chloride were quite similar. With both, the amount of growth progressively decreased as osmotic concentration was increased. Magnesium chloride depressed the growth considerably more than other chlorides at higher

concentrations. Vlamis and Jenny [1948] and Vlamis [1949] observed that lettuce plants made no growth in the soil saturated with Mg and by adding a soluble Ca salt, the toxicity of exchangeable Mg was completely overcome. W. P. Kelley [1951] proved that Mg saturated soils are highly toxic. Eaton [1950] reported that irrigation water of higher content of Ca++ and Mg++ than CO_3 and HCO_3 may develop salinity.

Materials and Methods

(1) *Preparations of samples*

Samples were air dried, ground in a mortar with wooden pestle and a representative fraction of the material passing through 2 mm. sieve was used for analysis [Piper, 1947].

(2) *Air dry moisture*

This was determined by drying a weighed quantity of soil in an electric oven at 105°C to constant weight and the loss in weight being expressed as a percentage [A.O.A.C. 1950].

(3) *Mechanical analysis*

The international 'A' method was followed, [≡Robinson and Richardson (1933)] with pre-treatment of dilute HCl to destroy carbonates, and finally dispersed with N. caustic soda ; silt and clay were determined by pipette method and the fine sand by decantation method. Coarse sand was separated by sieving.

(4) *Hydrogen-ion concentration* (*p*H)

(*Soil : Water ratio 1 : 2·5*) : The *p*H below 7·5 was determined by the Quin-Hydron electrode method using saturated Calomel electrode as a reference electrode. pH values above 7·5 were determined by using glass electrode.

(5) *Water soluble salts*

Preparation of water extract of soils (*Soil : Water ratio 1 : 5*) : Two hundred grams of the soil were treated with 1000 c.c. of distilled water and left overnight with occasional shakings. The heavier particles were allowed to settle down and the supernatant liquid decanted through Pasteur Chamber-land filter candle under pressure. The water extract of soils was analysed immediately for carbonates, bi-carbonates and chlorides and later for the rest of the constituents.

(*a*) *Total water soluble salts :* One hundred c.c. of the aliquot from the water extract of soils was evaporated to dryness in a weighed silica basin on a water bath and then dried at 105° C in an oven and weighed to constant weight. From the increase in the weight of silica basin, the percentage of total soluble salts was calculated.

(*b*) *Carbonates and bicarbonates :* These were determined in an aliquot of 100 c.c. by titrating with N/50 H_2SO_4, first with phenolpathalein as an indicator for carbonates and titration was continued for bicarbonates with the same acid using methyl orange as an indicator [Piper, 1947].

(*c*) *Chlorides :* Five to 10 c.c. of the extract, depending on the chloride content was titrated against standard silver nitrate solution using one per cent potassium chromate as an indicator [Piper, 1947].

(*d*) *Sulphate* (*Gravimetric*) *:* Sulphates were precipitated with six per cent barium chloride solution, filtered and washed free of chlorides. The washed precipitate was dried, ignited and weighed as $BaSO_4$ multiplying the weight by 0·412, the weight of sulphate was known, from which the percentage in the soil was calculated.

(*e*) *Calcium :* It was precipited in a 100 c.c. aliquot as calcium oxalate in acetic acid medium with hot saturated ammonium oxalate and estimated volumetrically by titration against N/10 potassium permanganate solution [Piper, 1947].

(*f*) *Magnesium :* Magnesium was determined in the filtrate from calcium, by precipitation as a magnesium ammonium phosphate, which is washed, dried and dissolved in N/10 H_2SO_4, and the excess of acid was titrated back with N/10 Na(OH).

(*g*) *Potassium :* It was determined by the cobalt nitrite method [Piper, 1947].

(6) *Hydrochloric acid extract of soil*

The A.E.A. provisional method 1931 was followed [Piper, 1947] to determine the hydrochloric acid extract of the soil.

(*a*) *Potassium :* It was determined in the HCl extract volumetrically by cobalt nitrite method [Piper, 1947].

(*b*) *Phosphoric acid :* It was determined in HCl extract by precipitating as phospho-amino molybdate and estimating volumetrically (A.O.A.C. 1950).

(7) *Total nitrogen*

It was determined by Kjeldahl's method.

(8) *Available potassium and phosphoric acid*

It was determined by Dyer's one per cent citric acid method.

Soil Profiles

For the purpose of this study, two villages which have shown considerable salt encrustation were selected, namely, Gheora and Kamruddin-Nagar.

The Gheora profile was studied on a plot owned by Shri Nambardar but left barren due to high concentration of salt. The middle part of the field which had a standing wheat crop at the time of sampling had also small scattered patches of white and barren soil. For studying the concentration of salts in the cropped area, two representative samples, one from upto nine inches depth and the other from nine inches to one foot and six inches depth were taken. Similarly, two such samples were taken from a barren plot. Two water samples were collected, one from the well and the other from the irrigation canal, both of which are used for irrigating the area. The depth of water table is only four feet and ten inches.

Description of profiles

Profile No 1 (Gheora)

Location, etc.	About one mile to the northern side of village Gheora. The area is nearly flat, growing salt resistant grasses such as *Sporobolus arabicus* and *Chloris montana*. The surface drainage is adequate.
Depth	
6 in.	Loose yellowish loam; structureless; a few roots present; no concretions, no effervescence with dil. HCl; white encrustation of salts.
1 ft. 6 in.	Yellowish loam; structureless; hard and compact; no effervescence with dil. HCl; no plant roots.
1 ft. to 1 ft. 10 in.	Single grain structure; yellowish grey loam; no effervescence with dil. HCl; grey streaks and mottlings seen throughout, no roots.
1 ft. 10 in. to 3 ft.	Yellowish loam; structureless; weak effervescence with dil. HCl; small calcium nodules (*kankar*) present throughout the profile.
3 ft. to 4 ft. 2 in.	Yellowish loam; single grain structure; compact; fine roots; medium sized *kankars* were seen accumulated in layers; fairly moist throughout; vigorous effervescence with dil. HCl.
4 ft. 2 in. to 4ft. 10 in.	Sandy yellow soil; compact; a bed of large irregular shaped calcareous nodules; strong effervescence with dil. HCl.; water table was reached at four feet and ten inches depth.

Profile No 2 (Kamruddin Nagar)

The second profile was taken from the cultivated field owned by Shri Kana Nambardar. The area was under wheat. Also samples of water from three wells, which are used for the irrigation, were collected for analysis.

Location, etc.	About a mile to the south of the village Kamruddin Nagar ; low lying area ; very sparse vegetation, surface drainage fair ; white patches were seen here and there. The growth of the wheat crop in the area is very stunted. No water table was found upto six feet two inches.
Depth	
6 in.	Whitish-grey loam ; loose ; structureless ; whitish salt encrustation at the top ; fine plant roots densely spread out ; no effervescence with dil. HCl.
6 in. to 1 ft. 6 in.	Whitish-grey loam ; hard and compact ; single grained structure ; roots very thinly spread out.
1 ft. 6 in. to 2 ft. 6 in.	Whitish-grey loam ; mottling of reddish brown colour ; weakly developed blocky structure with pointed ends ; effervescence with the HCl due to small calcium nodules (*kankar*).
2 ft. 6 in. to 3 ft. 6 in.	Whitish-grey loam, vigorous effervescence with dil. HCl ; roots seen here and there ; krotovinas at 50 ft. depth.
3 ft. 6 in. to 5 ft. 6 in.	Yellowish loam, roots are completely absent ; *kankars* are seen throughout ; strong effervescence with dil. HCl.
5 ft. 6 in. to 6 ft. 2 in.	Yellowish colour predominant ; compact with concretions ; superficial deposits of calcium carbonate ; complete absence of roots ; strong effervescence with dil. HCl.

Taking all the facts in consideration, the morphological features and vertical salt distribution in both the Delhi profiles suggest that the soils of the present study resemble the 'Solonchak' group.

Data and Discussions

(*1*) *Mechanical analysis*

The results of mechanical analysis of the profile samples are presented in Tables I and II.

TABLE I

Mechanical analysis (Village Gheora—Profile I)

Depth	Percentage on oven dry basis						
	Moisture of air dry soil	Coarse sand 2·0 mm. —·02 mm.	Fine sand ·2 mm. —·02 mm.	Silt ·02 mm. —·002 mm.	Clay <·002 mm.	$CaCO_3$	Textural class
0—6 in.	1·0	0·2	75·7	13·5	9·6	Traces	Sandy loam
6 in.—1 ft.	1·5	0·2	64·5	15·7	18·3	,,	Sandy loam
1 ft.—1 ft. 10 in.	1·5	0·2	56·1	20·4	23·1	,,	Sandy clay loam
1 ft. 10 in.—3 ft.	2·0	0·2	58·0	16·8	25·2	1·38	Sandy clay loam
3 ft.—4 ft. 2 in.	2·0	0·1	61·4	14·7	22·8	2·90	Sandy clay loam
4 ft. 2 in.—4 ft. 10 in.	1·5	0·1	64·5	11·1	19·7	7·6	Sandy loam

TABLE II

Mechanical analysis (Village Kamruddin Nagar—Profile II)

Depth	Percentage on oven dry basis						
	Moisture of air dry soil	Coarse sand 2·0 mm. —·02 mm.	Fine sand ·2 mm. —·02 mm.	Silt ·02 mm. —·002 mm.	Clay <·002 mm.	$CaCO_3$	Textural classes
0—6 in.	0·3	0·2	69·0	13·1	16·9	Traces	Sandy loam
6 in.—1 ft. 6 in.	0·5	0·2	70·0	6·7	22·1	,,	Sandy clay loam
1 ft. 6 in.—2 ft. 6 in.	1·0	0·1	72·6	9·0	17·6	1·36	Sandy loam
2 ft. 6 in.—4 ft. 6 in.	0·7	0·1	72·4	9·4	16·7	1·26	Sandy loam
4 ft. 6 in.—5 ft. 6 in.	1·0	0·1	79·4	11·3	8·3	1·76	Sandy loam
5 ft. 6 in.—6 ft. 2 in.	0·8	0·1	63·6	27·9	6·8	2·11	Sandy loam

With profile I (Gheora), the clay content increases with the depth upto 36 ft. being 9·6 per cent at the top and 25·2 per cent at the third feet followed by a little decrease in successive two bottom layers, upto 19·7 per cent at four feet two inches to four feet ten inches depth. With profile II, it increases from 16·9 per cent to 22·1 per cent to the second layer (6 in. to 1 ft. 6 in.) and then decreases with the depth, the lowest percentage of clay being 6·8 at the bottom layer (5 ft. 6 in. to 6 ft. 2 in.). The silt content in profile I increases with the depth upto one foot ten inches and then there is a decrease upto four feet ten inches whilst in profile II, the silt distribution is uneven, 13·1 per cent at the top and almost double the quantity is found

at the bottom, i.e. 27·9 per cent. The percentage of fine sand fraction is very high in both the profiles. In profile I, the fine sand tends to be minimum (56·1 per cent at an intermediate depth ; the percentage at the top being 75·7 per cent and at the bottom 64·5 per cent). In profile II, there is a gradual increase in fine sand with the depth upto five feet and six inches after which there is a decrease. Coarse sand is negligible in all horizons of both the profiles.

In profile I, the first, second and sixth horizons contain sandy loam soil while all other horizons are sandy clay loam in texture. Profile II possesses sandy loam texture in all the horizons except the second which has a sandy clay loam texture.

Carbonates : The carbonate content of these soils seems to be high at the bottom. In both the profiles carbonates increase with the depth. Profile I has 7·6 per cent $CaCO_3$ at four feet two inches to four feet ten inches while the profile II has only 2·11 per cent at five feet six inches to six feet two inches depth. The percentage of carbonate in the surface layer is in traces and in a noduled form.

Moisture : The moisture content of these air dry soils varies between one to two per cent in profile I, and 0·3 per cent to one per cent in profile II, and varies with the relative percentage of clay in the soils.

(*2*) *Chemical analysis of the soil*

Analysis of the HCl extract : The soils were digested with hydrochloric acid (constant boiling point 110°C). The results of the analysis of the extracts are shown in Tables III and IV.

TABLE III

Analysis of HCl extract : (Village Gheora—Profile I)
(percentage on oven dry basis)

P_2O_5	K_2O	CaO	MgO	Fe_2O_3	Al_2O_3	HCl insoluble matter
0·148	0·296	0·742	0·514	2·480	3·570	88·850
0·192	0·357	0·588	0·565	3·600	4·350	83·630
0·132	0·357	0·714	0·706	4·080	4·855	83·170
0·068	0·510	0·742	0·756	4·200	4·975	82·140
0·173	0·393	0·798	0·771	4·480	5·070	81·830
0·179	0·401	4·900	0·101	4·000	5·025	77·200

TABLE IV

Analysis of HCl extract (Village Kamruddin Nagar—Profile II)

(percentage on oven dry basis)

P_2O_5	K_2O	CaO	MgO	Fe_2O_3	Al_2O_3	HCl insoluble matter
0·145	1·108	0·410	0·548	2·320	2·315	92·340
0·272	0·459	0·392	0·141	3·200	4·675	87·330
0·331	0·471	0·630	0·494	3·360	4·865	86·630
0·556	0·107	0·854	0·385	3·040	4·560	86·620
0·559	0·085	1·680	0·121	4·160	3·285	85·460
0·201	0·228	2·394	0·165	4·000	3·440	86·020

It will be seen in profile I (Table III) that the acid insoluble material decreases with the depth. Top layer contains 88·85 per cent and the bottom one 77·20 per cent. Profile II (Table IV) also shows generally a gradual decrease of HCl insoluble matter with the depth except at the bottom-most layer. The high percentage of HCl insoluble matter in both profiles is obviously due to higher percentages of fine sand in both the profiles.

The HCl soluble P_2O_5 in profile I shows the minimum value of 0·068 per cent at an intermediate depth (1 ft. 10 in. to 3 ft.) and then it increases with the depth, the value at the deepest layer (4 ft. 2 in. to 4 ft. 10 in.) being 0·179 per cent. In profile II, the percentage of HCl soluble P_2O_5, increases upto five feet and six inches and then decreases. The intermediate layers of Kamruddin Nagar profile are richer in P_2O_5 content than the Gheora profile.

HCl soluble K_2O in profile I shows a maximum value at an intermediate layer of the profile (0·510) whilst in profile II, it generally decreases with the depth, with an increase in the bottom-most layers.

HCl soluble CaO increases with the depth in both the profiles.

The total nitrogen and available P_2O_5 and K_2O percentages from both the profiles are given below in Table V and VI.

TABLE V

Analysis of profile sample (Village Gheora)

Depth	Total nitrogen percentage	Total P_2O_5 percentage	Available percentage	
			P_2O_5	K_2O
0—6 in.	0·037	0·148	0·024	0·004
6 in.—1 ft.	0·041	0·192	0·010	0·004
1 ft.—1 ft. 10 in.	0·040	0·132	0·018	0·003
1 ft. 10 in.—3 ft.	0·032	0·068	0·008	0·011
3 ft.—4ft. 2 in.	0·029	0·173	0·007	0·004
4 ft. 2 in.—4 ft. 10 in.	0·026	0·179	0·001	0·002

TABLE VI

Analysis of profile samples (Village Kamruddin Nagar)

Depth	Total nitrogen percentage	Total P_2O_5 percentage	Available percentage	
			P_2O_5	K_2O
0—6 in.	0·005	0·145	0·066	0·046
6 in.—1 ft. 6 in.	0·001	0·272	0·117	0·032
1 ft. 6 in.—2 ft. 6 in.	0·001	0·331	0·168	0·030
2 ft. 6 in.—4 ft. 6 in.	0·001	0·556	0·167	0·008
4 ft. 6 in.—5 ft. 6 in.	0·004	0·559	0·158	0·009
5 ft. 6 in.—6 ft. 2 in.	0·007	0·201	0·049	0·009

The Tables V and VI show that both the soils are poor in nitrogen. The top layer of profile I (6 in.) is fair in available P_2O_5, but bottom layers are poor. On the other hand, the citric acid soluble P_2O_5 is very high in the case of profile II. Profile I is poor in available K_2O throughout the profile layers while profile II is also poor in available K_2O except in the top layer.

Both the soils are fairly rich in HCl soluble MgO. In fact, in profile II, the top layer is richer in MgO as compared to CaO. The presence of such high percentage of magnesium in the soil is interesting.

The molecular ratio of HCl soluble CaO to MgO in the two profile samples are shown in Table VII.

TABLE VII

HCl soluble CaO and MgO ratio

Depth	Village Gheora				Depth	Village Kamruddin Nagar			
	CaO per cent	MgO per cent	Ratio			CaO per cent	MgO per cent	Ratio	
			CaO :	MgO				CaO :	MgO
0—6 in.	0·742	0·514	1·03	1	0—6 in.	0·410	0·548	0·54	1
6 in.—1 ft.	0·588	0·565	0·74	1	6 in.—1 ft. 6 in.	0·392	0·141	1·98	1
1 ft.—1 ft. 10 in.	0·714	0·706	0·72	1	1 ft. 6 in.—2 ft. 6 in.	0·630	0·494	0·091	1
1 ft. 10 in.—3ft	0·742	0·756	0·69	1	2ft. 6 in.—4 ft. 6 in.	0·854	0.385	1·58	1
3 ft.—4 ft. 2 in.	0·798	0·771	0·73	1	4 ft. 6 in.—5 ft. 6 in.	1·680	0·121	9·93	1
4 ft. 2 in.—4 ft. 10 in.	4·900	0·101	34·7	1	5 ft. 6 in.—6 ft. 2 in.	2·394	0·165	10·30	1

It will be seen from Table VII that in both the profiles, the CaO : MgO ratios of the horizon samples are very low. This low ratio of CaO : MgO at the top horizons might be one of the causes of the observed poor growth of wheat crop in the locality.

Water soluble salts

The composition of the soil extract is given in Table VIII and IX.

TABLE VIII

Analysis of water extract of soils (Village Gheora)

Depth	M. eq. per 100 gm. of soils						Total soluble salts per cent	pH
	HCO_3	Cl	SO —	Ca ++	Mg ++	K+		
0— 6 in.	·20	8·51	8·00	4·59	2·88	·03	1·32	7·5
6 in—1 ft.	·21	4·48	3·44	1·63	1·23	·28	0·72	7·6
1 ft.—1 ft. 10 in.	·21	4·31	5·85	0·75	2·33	·13	0·61	7·7
1 ft. 10 in.—3 ft.	·31	4·59	3·40	0·80	2·33	·08	0·79	7·9
3 ft.—4 ft. 2 in.	·36	6·00	3·44	1·50	3·54	·03	0·64	8·1
4 ft. 2 in.—4 ft 10 in.	·36	6·59	3·52	1·50	1·43	·18	0·73	8·0

TABLE IX

Analysis of water extract of soils (Village Kamruddin Nagar)

Depth	M. eq. per 100 gm. of soils						Total soluble salts per cent	pH
	HCO_3	Cl	SO4	Ca +++	Mg ++	K+		
0—6 in.	0·39	4·31	1·40	1·27	0·82	Trace	0·25	715
6 in.—1 ft. 6 in.	0·28	2·20	0·46	0·50	0·33	,,	0·16	7·6
1 ft. 6 in.—2 ft. 6 in.	0·33	1·27	1·13	0·40	0·41	,,	1·14	7·9
2 ft. 6 in.—4 ft. 6 in.	0·44	1·89	1·38	0·68	0·58	,,	0·21	7·9
4 ft. 6 in.—6ft. 6 in.	0·39	2·45	1·29	0·99	0·53	,,	0·31	8·0
6 ft. 6 in.—7 ft. 2 in.	0·39	3·01	1·42	0·68	0·99	,,	0·42	8·0

(i) In respect of the depth distribution, the highest concentration of soluble salts is found on the top in profile I.

The distribution of soluble salts in both the profiles I and II are different. The percentage of total soluble salts in Kamruddin Nagar profile is much less as compared to those in Gheora profile.

(ii) In profile I, the water table is at four feet and ten inches from the surface. It can be said that the high water table might have contributed to the presence of

higher percentage of salt. Profile II does not contain high percentage of salts as compared to the profile I and the water table is also low in this case.

(iii) Judging in the above light, it can be said that profile I (Gheora), which shows the distribution of salt between 0·61 per cent to 1·33 per cent comes under the grade medium to very strong saline soil. Profile II (Kamruddin Nagar) possesses lower percentage of salts as compared to profile I, ranging from 0·025 per cent to 0·42 per cent, and hence, can be called as weak saline but has a general tendency towards saline side.

*p*H and total soluble salts of the surface and sub-surface soil samples from areas adjacent to profile I in Gheora village are given in Table X.

TABLE X

*p*H *and total soluble salts*

Samples	Plot cropped with wheat		Plot without crop	
	Total soluble salt per cent	*p*H	Total soluble salt per cent	*p*H
Surface samples 9 in.	0·062	7·9	0·88	8·0
Sub-soil samples 9-18 in.	0·22	7·6	0·90	7·7

The data of the salt content show that the salt content of the surface samples of the plots without crop are above 0·4 per cent and, therefore, the soils are not good for growing crop.

Analysis of well, canal and ground water

It was felt desirable to examine in this connection, the composition of the water of the wells both the villages used for irrigation and also the ground water of the Gheora profile.

Gheora village is under the command of a canal whose water also was analysed for the sake of comparison. The data are shown in Tables XI and XII.

TABLE XI

Composition of water (Village Gheora)

Source	Milliequivalents per litre							Total dissolved solids pp. 100,000	*p*H
	CO_3^{--}	HCO_3^-	SO_4^{--}	Cl—	K+	Mg++	Ca++		
Water from adjacent well	0·40	5·61	23·13	2·20	0·80	3·61	1·45	209	7·2
Canal water	..	1·79	2·92	1·00	0·91	2·10	1·00	80	7·7
Ground water	0·40	1·82	46·05	0·30	1·09	30·70	86·94	2552	8·3

TABLE XII

Composition of well water (Village Kamruddin Nagar)

	Milliequivalents per litre							Total dissolved solids pp. 100,000	pH
	CO_3^{--}	HCO_3^{-}	SO^{--}	Cl-	K+	Mg++	Ca++		
Well owned by shri Ful Singh	1·03	7·96	1·52	46·45	1·37	12·90	4·08	375	8·0
Well owned by Shri Chuna and Parsu	..	6·20	3·05	31·06	0·36	9·89	4·44	320	8·0
Adjacent well of Shri Kana Numberdar	..	6·20	7·21	102·90	9·97	25·69	7·49	790	8·3

Tables XI and XII show that the well water in these areas, which is used for irrigation, contains over 209 parts per 100,000 including 23·13 m.eq./litre, SO_4^{--}, 5·61 m.eq./litre HCO_3^- and 2·2 m.eq./litre of chloride. The water is not good for irrigation purpose. The well water (adjacent to the profile II area) contained higher amount of Mg++ (25·69) m.eq./litre, and Ca++ (7·49 m.eq./litre) than the CO_3^{--} (nil) and HCO_3^- (6·20 m.eq./litre) and contains very high amount of soluble salts, i.e. 790 parts per 100,000 which might have rendered the soil saline through its application.

The salt content, as it affects the suitability of the water for irrigation, relates both to the kind and the nature of the salt. The classification of irrigation water in relation to the total salt content as given by C.C. Shah [1951] is given in Table XIII.

TABLE XIII

Total soluble salt parts per 100,000	Suitability for irrigation
68·4	Excellent
85·0	Good
157·3	Medium, tolerable
185·3	Medium, fairly tolerable
352·0	Bad
358·0	Bad
524·5	Unfit

The water from the canal in Gheora village contains 60·5 parts per 100,000 of total soluble salts. The major portion of the salt is represented by sulphate, while chloride is only 1 m.eq./litre. Total soluble salts content (60·5 parts per 100,000) is satisfactory for irrigation purposes. The ground water of Gheora village contains 2552 parts of total soluble salts per 100,000, of which chloride forms the major portion.

The high water table (4 ft. 10 in.) is responsible for accumulation of white encrustation of salt at the surface.

Joachim [1941] quoted that in Sind, a sub-soil water less than 120 parts of soluble salts per 100,000 is considered safe ; one containing 120-1000 parts per 100,000 is dangerous ; one with 1000-3000 parts per 100,000 is bad and one with more than 3000 parts per 100,000 is very bad. Judged from this point of view, the ground water in Gheora village is bad.

Well owned by Shri Fulsingh (*Table XII*). This well water contains 375 pp 100,000 of total soluble salts. C_a^{++} is only 4·08 m.eq./litre. The amount of chloride is much high as compared to SO_4^{--} and forms the major portion of anions. The *p*H is 8·0. The water is unfit for irrigation.

Well owned by Shri Chuna and Shri Parsu. The total soluble salts are 320 parts per 100,000. The content of *Cl* is 31·6 m.eq./litre. This water is not good for irrigation except that only tolerant crops can be grown for its use.

Well owned by Shri Kana Numberdar (*adjacent to the profile II area*). The well water contains very high quantity of total soluble salts, viz. 790 parts per 100,000 containing calcium 7·49 m.eq./litre. Chloride forms 90 per cent amount of anions. The *p*H is 8·3. This water is also quite unfit for irrigation.

Summary

(1) A study of morphological features and profile characteristics of two saline soils from Village Gheora and Kamruddin Nagar, from low lying areas of Delhi State has been made.

(2) The important distinguishing characteristics of these profiles are : colour texture, root distribution and reaction to dilute hydrochloric acid.

(3) All the soils are sandy loam to sandy clay loam. The concentration of water soluble salts decreased with the depth in the Gheora profile from 1·32 per cent to 0·61 per cent upto one foot and ten inches and again increased from 0·61 (1 ft.10 in.) to 0·73 per cent (4 ft. 10 in.). In the Kamruddin Nagar profile the total salt concentration first decreased from 0·25 to 0·14 per cent at 2 ft. 6 in. ; and then increased from 0·14 per cent to 0·42 per cent at depth (7 ft. 2 in.).

(4) The *p*H of water extract (1 : 2·5) increases with depth in the case of both the profiles, indicating increasing alkalinity at lower layers. Water of adjacent wells at both the places contains high amount of total soluble salts, namely 790 and 209 parts per 100,000 at Gheora and Kamruddin Nagar, respectively. However, the canal water of Gheora village which contains total soluble salts, amounting to 60·5 parts per 100,000 is good for irrigation.

(5) The morphological feature and the chemical and physicochemical properties suggest that these soils come under the 'Solanchak' group.

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A COMPARISON OF DIFFERENT METHODS OF DISPERSING CALCAREOUS SOILS

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THE fundamental basis for the efficiency of different dispersing agents lies in their power to increase the negative potential of the clay particles. It has been established by Marshal [1931], Jenny, *et al.*, [1935] and Puri [1936] that the nature of the exchangeable base has a profound influence on the dispersion of a soil in water. Sodium and lithium give the highest dispersion and this has been generally ascribed to the hydration of these ions, which are responsible for increasing the negative potential of the soil colloids. Puri [1938] further concluded that the maximum dispersion, both by auto-disintegration as well as shaking, was attained at *p*H 10·8. But the manner of approach to this maximum was different for different soils. Chatterji and Dass [1935] found that *p*H was not the only factor in determining the dispersion of soils.

Green [1933] observed that ordinary deflocculating agents were not effective in dispersing calcareous soils. Treating the soils with acids is also not desirable as it will remove considerable amount of iron, aluminium and silica along with calcium carbonate. Tyner, *et al.*, [1939] investigated the use of sodium metaphosphate for dispersing the soils especially the calcareous ones.

Experience has shown that no single method of analysis can be applied to all types of soils.

In the light of these observations, it was considered essential to study in detail the effectiveness of the different dispersing agents in order to achieve the maximum results.

Experimental Details

The following methods of dispersion were tried:

(1) *Sodium carbonate.* Sodium hydroxide method. Addition of sodium carbonate (equivalent to the exchangeable calcium in the soil) and sodium hydroxide to raise the *p*H to 10·8.

(2) *Sodium oxalate.* Addition of sodium oxalate equivalent to the exchangeable calcium in the soil and sodium hydroxide to raise the *p*H to 10·8 [Puri, 1936].

(3) *Sodium silicate.* Addition of sodium silicate in order to replace exchangeable calcium and raise the *p*H to 10·8.

(4) *Ammonium carbonate method.* Boiling the soil with normal ammonium carbonate in order to reduce the volume to one-half and then the addition of sodium hydroxide to raise the *p*H to 10·8 [Puri, 1935].

(5) (*a*) Boiling the soil suspension to reduce the volume to one-half and then adding sodium hydroxide to raise the *p*H to 10·8.

(*b*) Boiling the soil suspension in order to reduce its volume to one-half, then making it upto the original volume and again reducing it to one-half by boiling.

(6) *Hydrochloric acid—sodium hydroxide method.* Leaching the soil with N/2 hydrochloric acid followed by washing with distilled water, till the filtrate is free of the chloride ions, and then shaking after the addition of sodium hydroxide to the filtrate to increase the *p*H to 10·8.

(7) *International method.* Destruction of organic matter with H_2O_2 followed by leaching with dilute hydrochloric acid and washing with distilled water, finally shaking after the addition of sodium hydroxide.

(8) *Sodium pyrophosphate.* Shaking the soil with the addition of normal sodium pyrophosphate.

(9) *N. sodium pyrophosphate* plus *N. sodium carbonate or N. sodium hydroxide.* Five c.c. of this mixture in 1000 c.c. of suspension containing 10 gm. of soil.

(10) *N. sodium dihydrogen-phosphate alone and in the presence of N. sodium hydroxide.* Five c.c. of this mixture in 1000 c.c. of suspension containing 10 gm. of soil.

(11) *N. sodium ferrocyanide.* Five c.c. of this solution in 1000 c.c. of suspension containing 10 gm. of soil.

(12) *Normal sodium ferrocyanide* plus *N. sodium hydroxide.* Five c.c. of this mixture in 1000 c.c. of the suspension containing 10 gm. of soil.

(13) *N. sodium metaphosphate.* Five c.c. of this solution in 1000 c.c. of suspension containing 10 gm. of soil.

(14) *N. sodium metaphosphate* plus *N. alkali.* While trying this method, i^t was found that even N/2 $Na(PO_3)_6$ *plus* N/2 Na_2CO_3 or N/2 NaOH proved efficient. The strength of the solution depends upon the type of soil. The greater the base exchange capacity, the higher should be the strength of mixture, e.g. for montmorillonite type of soils it is better to use normal solutions.

(15) *Trituration.* Trituration was carried out by gently rubbing the sample in a mortar with a rubber pestle for about 30 to 45 minutes and finally making the desired volume.

The soil samples in the second set were triturated in dry and wet conditions in the presence of coarse sand (retained on mesh 25). In the former case, no water was added and the soil and dry sand were gently rubbed together in a pestle and mortar, while in the latter, trituration was accomplished in the presence of water.

(16) *Shaking with coarse sand.* Soil suspension containing varying percentages of coarse sand (retained on 25 mesh) was shaken in an end over end shaker for about 24 hours and the desired volume made finally.

The soils used for comparing the different methods of dispersion belonged mostly to the Kaolinite group except the soils (Reg. No. 4, 5, 6 ; Table III) which were obtained from Poona and the black cotton soil (Table II) related to Montmorillonite type. The organic matter was low in all the cases except in black cotton soil where it was 0·612 per cent.

Discussion of Results

The methods outlined above fall into four categories.

(*a*) The first four (1-4) methods depended on the direct replacement of exchangeable calcium by sodium without the removal of calcium carbonate from the soil.

(*b*) Methods 6 and 7 aimed at the removal of both the exchangeable calcium and calcium carbonate from the soil. The soil acidoid was finally converted into sodium soil and its *p*H raised to about 10·8 by the addition of equivalent amount of sodium hydroxide.

(*c*) In methods 8 to 14 the following salts of sodium were used for the dispersion of soil colloids.

(i) Sodium ferrocyanide

(ii) Sodium pyrophosphate

(iii) Sodium dihydrogen phosphate

(iv) Sodium metaphosphate

(*d*) Methods 5, 15 and 16 aimed at the physical procedure of dispersing the soils.

(i) Boiling

(ii) Trituration

(iii) Shaking with coarse sand

Table I gives the comparative clay percentages of soils dispersed with the following dispersing agents.

TABLE I

Effect of different dispersing agents on the dispersion of soils
(Clay percentage after treating the soils with different dispersing agents)

Serial number	Reg. No.	Percentage calcium carbonate	Na_2CO_3 and NaOH	Sodium oxalate and sodium hydroxide	Ammonium Carbonate	Hydrochloric acid and NaOH	International method	NaH_2PO_4	NaH_2PO_4 and NaOH	Boiling alone	Boiling and NaOH	Sodium metaphosphate and NaOH	Trituration
			1	2	3	4	5	6	7	8	9	10	11
1	1206	1·0	12·0	12·4	9·0	14·6	12·9	10·0	9·6	8·0	11·6	16·0	15·5
2	156	3·3	14·5	14·5	10·0	17·3	16·8	8·0	8·0	5·7	10·2	18·6	18·2
3	229	5·0	18·7	16·0	18·2	18·7	20·1	16·1	18·8	13·7	20·0	21·7	20·8
4	233	10·0	18·6	17·4	16·3	24·3	24·3	12·0	18·4	9·0	22·0	26·9	23·2
5	263	14·5	21·2	20·9	8·1	25·5	25·7	15·2	19·8	10·8	20·4	28·7	24·6

1. Sodium carbonate plus sodium hydroxide
2. Sodium oxalate plus sodium hydroxide
3. Ammonium carbonate
4. Hydrochloric acid plus sodium hydroxide
5. International method
6. Sodium di-hydrogen phosphate
7. Sodium di-hydrogen phosphate plus sodium hydroxide
8. Boiling
9. Boiling plus sodium hydroxide
10. Sodium metaphosphate plus sodium hydroxide
11. Trituration

The results of clay percentages revealed that sodium metaphosphate and trituration were the best dispersing agents.

The second set of experiments was carried out to investigate the efficiency of the remaining dispersing agents listed under experimental head.

(*a*) Acid-treated black cotton soil containing about 55 per cent of clay (particles below 0·002 mm.) was dispersed with the varying amounts of sodium silicate (Table II).

TABLE II

Effect of varying amounts of sodium silicate on the dispersion of acid treated black cotton soil containing 55·5 per cent clay

Serial No.	Sodium silicate added in m.e/100 gm. Soil	*p*H	Clay per cent
1	—*nil*—	4·45	8·60
2	5·0	5·40	11·38
3	10·0	5·75	13·63
4	15·0	6·00	14·63
5	20·0	6·20	16·18
6	30·0	6·60	16·15
7	40·0	7·40	20·28
8	50·0	9·10	14·30
9	60·0	9·80	13·13
10	70·0	10·40	4.27
11	80·0	10·65	11·64
12	100·0	10·80	11·95
13	150·0	10·95	13·71
14	200·0	11·05	16·58

From these results it was clear that sodium silicate could not effect complete dispersion of a soil. This might be due to the release of a much larger amount of free silica which made it incapable of being completely dispersed even at *p*H 11·05.

The third set of experiments was conducted to study the comparative efficiency of the various methods employed for dispersing soils, e.g. sodium carbonate and sodium hydroxide method, trituration, shaking with coarse sand, ferro-cyanide, sodium pyrophosphate and sodium metaphosphate as deflocculating agents. For studying the effect of coarse sand (retained on 25 mesh), it was admixed with soil upto 300 per cent and the soil suspension shaken for 12 hours in an end over end shaker. The results of clay percentages are presented in Tables III and IV.

TABLE III

Comparative effect of sodium metaphosphate, sodium carbonate, sodium pyrophosphate, sodium ferrocyanide plus sodium hydroxide and trituration as deflocculating agents. (clay percentage, particles below 0·002 mm. of soils treated with different deflocculating agents)

Serial No.	Reg. No.	Ca CO_3 percentage	Na_2CO_3 and Na OH	Sodium meta-phosphate	Sodium meta-phosphate plus Na_2 OH	Sodium pyro-phosphate	Sodium pyro-phosphate plus Na_2 OH	Potassium ferro-cyanide	Potassium ferro-cyanide plus Na_2 OH	Trituration	Trituration with dry sand	Trituration with wet sand	Remarks
1	962	0·26	17·45	20·45	24·96	20·45	20·60	14·48	20·96	25·68	24·16	28·08	
2	961	0·33	15·45	18·34	21·68	17·39	18·40	13·12	18·4	25·10	18·18	28·29	
3	958	0·39	12·95	14·12	15·15	13·00	13·50	14·00	15·4	25·60	19·68	26·48	
4	963	0·52	19·10	22·68	27·68	18·68	19·80	12·86	19·00	30·57	24·95	31·80	
5	955	0·52	10·90	13·18	15·90	13·0	13·60	13·4	15·4	19·70	20·80	27·20	
6	959	0·78	9·90	14·68	23·35	11·93	12·50	11·4	22·8	21·34	21·45	22·38	
7	965	1·04	18·0	19·69	23·68	19·80	20·90	14·9	23·06	27·80	26·75	27·80	
8	956	1·04	11·95	14·68	16·15	14·25	14·95	11·9	16·6	22·72	22·94	23·12	
9	953	1·30	14·50	18·0	20·10	18·01	19·40	15·7	22·0	20·28	23·32	24·64	
10	957	1·36	17·85	21·45	25·30	18·56	19·90	18·9	21·50	26·60	26·72	28·64	
11	970	1·69	14·60	18·69	24·95	16·68	19·75	13·69	22·9	21·28	21·57	23·80	
12	966	1·92	18·0	20·46	21·98	18·95	21·45	17·65	21·56	18·00	19·75	22·20	
13	964	3·06	19·1	24·69	27·0	22·09	24·69	17·95	26·5	29·36	30·40	32·48	
14	967	3·84	17·85	23·65	31·0	21·45	25·48	13·45	20·30	28·64	32·50	32·65	
15	960	4·91	13·10	24·65	27·70	18·9	25·60	14·60	20·25	21·90	22·90	24·98	
16	942	5·98	15·20	21·45	25·69	20·2	21·95	13·30	18·20	27·44	27·98	28·16	
17	947	7·28	17·20	20·69	23·65	19·45	22·0	11·75	18·95	25·52	26·09	26·52	
18	945	7·51	17·88	23·42	26·98	21·48	24·69	12·30	19·76	24·40	28·80	28·82	
19	5	9·50	16·45	20·25	42·85	23·80	37·05	18·45	31·35	34·55	36·99	39·90	
20	6	10·50	35·95	55·45	56·49	51·55	53·47	27·98	49·45	45·00	46·55	53·00	
21	4	11·20	14·75	28·95	28·75	27·65	28·75	12·68	28·20	25·45	30·05	31·00	

Table IV

Effect of coarse sand on the dispersion of soil as compared with sodium metaphosphate and trituration methods.

Serial No.	Dispersing agent	Clay percentage		
		900	901	902
1	Na_2CO_3 and Na OH	14·95	16·45	35·9
2	Sodium metaphosphate	33·75	23·69	42·85
3	Grinding with wet sand	31·0	24·0	39·9
4	Mechanical shaking with 10 per cent sand	12·35	13·45	24·9
5	,, 28 per cent sand	14·05	15·65	25·6
6	,, 30 per cent sand	15·55	17·20	28·7
7	,, 40 per cent sand	15·75	18·60	29·2
8	,, 50 per cent sand	16·75	19·20	29·6
9	,, 60 per cent sand	18·45	19·69	29·8
10	,, 70 per cent sand	20·45	20·00	29·85
11	,, 80 per cent sand	20·45	20·45	29·8
12	,, 100 per cent sand	20·65	20·95	30·2
13	,, 200 per cent sand	20·96	21·09	30·6
14	,, 300 per cent sand	21·2	22·9	30·6
15				

The results of Tables I to IV showed that the following reagents were fairly efficient as dispersing agents :

(*a*) Sodium metaphosphate and NaOH or Na_2CO_3

(*b*) Sodium pyrophosphate and NaOH or $Na_2 CO_3$

Trituration with wet sand also compared well with the above reagents in dispersing the soils. Shaking with coarse sand was not so efficient as dispersing the soil with metaphosphate or trituration. The results of dispersion were practically uniform above 100 per cent admixture of coarse sand.

The question naturally arises as to what was the role of sodium metaphosphate or sodium pyrophosphate in the dispersing of soils.

Sodium metaphosphate is a white vitreous mass. It is insoluble in water and melts at 617°C. It exists in different polymeric forms such as di-, tri-, tetra- and hexametaphosphate [Partridge, 1937]. Further, sodium metaphosphate reacts with calcium, magnesium and other divalent and trivalent cations forming highly complex undissociable compounds. It has, therefore, inferred that the dispersion property of sodium metaphosphate was due to the replacement of calcium by sodium in the exchange complex. The reverse reaction could not take place as the active calcium ion present in the suspension had already formed undissociable sodium calcium metaphosphate.

It is of interest to note that sodium hexametaphosphate is not very stable in solution. It decomposes to orthophosphate. The rate of decomposition increases with increase in temperature and decreases with increase in *p*H. A little percentage of sodium carbonate or sodium hydroxide stabilizes the hexametaphosphate solution. Therefore, it is always preferable to use alkaline sodium metaphosphate in the dispersion of soils.

The second question to be investigated was the probable reaction of calcium carbonate with the different dispersing solutions—Calcium carbonate was shaken with water, 50 per cent sand, N. sodium carbonate plus N. sodium hydroxide, sodium metaphosphate plus alkali, sodium pyrophosphate and alkali, sodium oxalate plus sodium hydroxide, trituration and trituration with sand. The results are given in Table V.

TABLE V

Effect of different dispersing agents on the dispersion of calcium carbonate

Serial No.	Dispersing agent	Per cent clay particles below 0·002 mm.
1	Aqueous dispersion	4·0
2	Shaking with 50 per cent sand	14·5
3	Dispersion solution N. NaOH and N. $Na_2 CO_3$	12·5
4	Metaphosphate and alkali	34·25
5	Pyrophosphate and alkali	34·25
6	Metaphosphate	28·99
7	Pyrophosphate	30·10
8	Sodium oxalate and sodium hydroxide	13·29
9	Triturations	29·99
10	Trituration with sand	39·89

TABLE VI

Comparison of the efficiency of sodium carbonate plus sodium hydroxide, trituration and sodium metaphosphate as dispersing agents for soils containing varying proportions of calcium carbonate

Serial number	Sample No.	$CaCO_3$ percentage	Dispersion soil Na_2CO_3 and NaOH	Trituration alone	Trituration with sand	Sodium metaphosphate
1	1	0·195	12·75	24·4	24·68	24·60
2	2	0·26	8·2	19·64	24·0	23·69
3	3	0·260	17·45	25·68	28·08	24·96
4	4	0·26	18·1	25·2	29·6	20·60
5	5	0·325	15·45	26·1	28·29	21·68
6	6	0·52	19·10	30·56	31·80	27·68
7	7	0·65	17·5	24·28	28·8	24·58
8	8	0·78	16·9	23·6	29·8	21·98
9	9	0·935	13·75	26·32	27·16	24·69
10	10	1·00	19·6	24·6	26·6	24·56
11	11	1·10	18·9	19·56	21·16	21·96
12	12	1·040	18·00	27·8	27·8	23·68
13	13	1·26	16·5	19·24	23·88	19·23
14	14	1·690	19·00	21·28	23·8	24·95
15	15	1·915	18·00	18·00	22·2	21·98
16	16	1·96	14·6	21·4	24·44	21·64
17	17	3·055	12·65	29·36	32·45	27·50
18	18	3·855	17·85	28·64	22·60	31·00
19	19	5·98	15·2	27·44	28·12	25·69
20	20	7·505	15·9	24·0	28·84	20·98
21	21	9·5	16·45	34·55	39·9	42·85
22	22	10·5	35·9	45·00	53·00	56·49
23	23	11·2	14·95	25·45	31·00	28·75

The results clearly showed that sodium metaphosphate plus alkali and trituration were very successful in dispersing calcium carbonate. Hence both these methods would give complete dispersion with calcareous soils. Tyner [1939] also confirmed that the stabilization of calcium carbonate dispersion by $NaPO_3$ was due probably to the protective action of the gelatinous substance presumably $Ca(PO_3)_2 \times H_2O$ which was precipitated on calcium carbonate surfaces when these reacted with sodium metaphosphate. It seemed plausible, therefore, to investigate the efficiency of sodium metaphosphate and trituration methods in dispersing other types of soils. A number of soils were dispersed with sodium carbonate plus sodium hydroxide, trituration with and without sand and sodium metaphosphate. The results of clay percentages, embodied in Table VI, confirmed the above findings of the greater efficiency of sodium metaphosphate and trituration with wet sand as compared with the usual methods of dispersion with sodium hydroxide plus N. sodium carbonate.

Summarising the above discussion, any one of the following methods may be used for the dispersion of calcareous soils :

(i) Ten grams of soil are mixed with 150-200 c.c. of distilled water containing 5 c.c. of (N. sodium metaphosphate plus N. sodium carbonate or sodium hydroxide solution). For kaolinite type of soils having low base exchange capacity (upto 20 m.e.) even N/2 or N/4 sodium hydroxide may be used. The greater the base exchange capacity of a soil, the higher should be the strength and quantities of the dispersing solutions. The suspension is mechanically shaken for about 12 hours, after which the volume is made to 1000 c.c. and the different fractions are pipetted after definite intervals of time calculated from Stokes Law. Sodium pyrophosphate can also be used in place of sodium metaphosphate in dispersing the soils.

(ii) *Trituration with wet sand.* Ten grams of the soils containing ten grams of sand retained on mesh 25 and sufficient water for making a thin paste are gently rubbed in a mortar with a pestle for about 45 minutes. The paste is then finally made to the desired volume and the different fractions are pipetted as stated in method No 1.

Summary

The following conclusions were drawn from the results of the investigations :

1. Sodium hydroxide, sodium oxalate, sodium silicate international method, or ammonium carbonate cannot disperse the soils to their maximum values.

2. The dispersion of calcareous and other soils can be successfully carried out by any one of the following dispersing agents in their order of merits.

(*a*) Sodium metaphosphate plus alkali,

or

(*b*) Trituration with wet sand

or

(*c*) Sodium pyrophosphate plus alkali.

3. The maximum dispersion of calcareous soils by sodium metaphosphate or sodium pyrophosphate is most probably due to the protective action, of the gelatinous substance presumably $Ca(PO_3) \times H_2O$, being precipitated on calcium carbonate surfaces.

4. The physical method of trituration with wet sand not only removes the cementing agents from the soils but also disperses the finer fractions of the soils to their maximum limit.

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STUDIES ON NITROGEN FIXATION BY *AZOTOBACTER* OCCURRING IN TANK SILTS

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(With one appendix)

It has been recorded in previous papers [Sen and Asija, 1953, 1954] that when tank silts are mixed with soils having different reactions and mechanical compositions and the mixtures kept at a constant moisture content, equivalent to one-third their saturation capacities, in addition to nitrification, there are considerable fixations of nitrogen during a period of eight to ten weeks. Such fixation of nitrogen is not observed in untreated soils under the same conditions. To ascertain the factors responsible for fixation of nitrogen, when nitrification is also active, a study of the nitrogen fixing flora of the tank silts was undertaken. This consisted of isolation and study of the nitrogen fixing blue green algae and also of *Azotobacter* as might occur in the silts. As the fixation of nitrogen was observed under aerobic conditions in the laboratory and is likely to occur in the field when tank silts are applied to the soil, a study of the anaerobic nitrogen fixing organisms like *Clostridium* was left out.

It was at first considered doubtful whether *Azotobacter* occurred in the silts under anaerobic conditions. Henrici and McCoy [1938] counted from a few thousand to five hundred million aerobes per c.c. of lake mud. Mukherjee and Vishnoi [1936] found that the number of strictly aerobic bacteria in submerged soils, although much lower than that in ordinary soils, was sufficiently large. Aquatic form of *Azotobacter* such as *Azotobacter agilis* is known [Winogradsky, 1928 ; Bergey, 1948]. Occurrence of *Azotobacter* in the marine algae [Moore, Wheetley and Webster, 1921] and in the surface mucus of blue green algae in common agricultural soils [Wann, 1921 ; Jones, 1930 ; Allison and Morris, 1930 ; Allison and Hoover, 1935 ; Allison, Morris and Hoover, 1937] is also well-known.

The present investigation deals with the study of nitrogen fixation by strains of *Azotobacter* occurring in tank silts of 19 villages in West Bengal. It was felt that studies of the nitrogen fixing flora of tank silts collected under aseptic conditions would have given a truer picture of the aerobic microbiological population of such silts but as tank silts are generally applied to soil under air-dried conditions after storage for some time, such a study, nevertheless, was expected to throw light on the conditions as naturally occur in silts before application to soils for manurial purposes.

Material

The tank silts were collected from beds of tanks dried up during summer and were obtained through the courtesy of the Director of Agriculture, West Bengal. They were obtained from the following 19 villages in West Bengal :—Aurangabad, Beldanga, Diamond Harbour, Ghatal, Ghorsala, Gidni, Jangipur, Kalyanpur,

Khairagola, Khirapai, Khirasagar, Kulpi, Maldah, Nayagram, Noada, Rajnagar, Sirshia, Sonarpur and Suri. Tank silt was collected from two different tanks from the village Jangipur. The study, therefore, related to twenty samples of tank silts. The composition of the silts were reported earlier [Sen and Das, 1951]. Hygroscopic moisture, *p*H, P_2O_5 and CaO contents of the silts are given in Appendix I.

Methods

Isolation of pure cultures. One hundred c.c. of sterile Ashby's mannite solution (K_2HPO_4-0·2 gm., NaCl-0·2 gm., $MgSO_4$-0·2 gm., $CaSO_4$-0·1 gm., $CaCO_3$-1·0 gm., mannite-10·0 gm., distilled water-1000 c.c.) were inoculated with 1 gm. of tank silt and a loopful of the scum formed within approximately a week was plated in three successive dilutions in mannite agar. The organisms from the colonies of *Azotobacter* in the Petri dishes after five days incubation at 30°C. were examined under the microscope and then transferred to mannite agar slants by Pt. needle. Growth on the slants were re-examined. If found contaminated, a loopful of the growth on the slant was again transferred to fresh mannite solution and incubated and isolation of *Azotobacter* carried out by replating from the scum and ultimately by transfer to slants.

The morphological, cultural and physiological characteristics of the isolates were studied. Measurement of the organisms was carried out with the help of a stage and an ocular micrometer.

Growth characteristics on potato, mannite agar, nutrient gelatine and Ashby's solution were recorded. The organisms were tested for their action on sugars, broth, sugar-broths, milk, litmus milk and for their capacity for formation of indole and ammonia, and nitrate reduction, hydrolysis of starch and H_2S production. The methods followed were those detailed in the 'Manual of methods for pure culture study of bacteria' [Conn, 1951].

Action on sugars. Two basal media were used. One consisted of Ashby's minerals, the other peptone broth. Test-tubes containing about 15 c.c. of the solutions were sterilised for three consecutive days for 30 minutes each day with an inverted Durham tube in each for observation for production of gas in an insipitator. It was evident that CO_2 production in such could hardly be noticed due to the high solubility of the gas. It was detected qualitatively by aerating the solution after a week's growth and passing the gas through lime water which turned milky.

Indole production. Indole production was examined by Bohme's test by using 10 c.c. of the culture fluid in peptone broth and adding to it 5 c.c. each of solutions of para-dimethyl amino benzaldehyde in alcohol and a saturated aqueous solution of potassium persulphate.

Nitrate reduction. Sterilised nitrate peptone broth (containing 0·1 per cent KNO_3) was inoculated with the organism. The liquid was tested periodically for nitrites by Greiss-Illovsay's reagent (α-naphthylamine-sulphanilic acid) and for ammonia by Nessler's reagent.

Production of hydrogen sulphide. Production of hydrogen sulphide was examined by using lead acetate paper strips over the growth of the organisms in nutrient broth and also on mannite agar.

Liquefaction of gelatine. Inoculated tubes of gelatine (12 per cent) were incubated at 37°C. for a week and then kept in a refrigerator. The capacity of the gelatine to solidify was noted.

Hydrolysis of starch. Inoculated potato cylinders were flooded with a solution of iodine after a week's growth. The iodine was coloured blue. A drop of an inoculated 0·2 per cent solution of soluble starch in peptone broth after growth of ten days was mixed with a drop of weak solution of iodine. Development of a deep blue colour indicated that no hydrolysis of the starch took place.

Nitrogen fixation by the mixed flora. One hundred c.c. of Ashby's mannite solution kept in 250 c.c. flasks were inoculated in triplicates with 1 gm. each of tank silts and incubated at 30°C. for a fortnight. At the end of the period, the contents of the flasks were digested with H_2SO_4 for estimation of nitrogen by the Kjeldahl's method.

Nitrogen fixation by Azotobacter. To an agar slant showing good growth of the organisms were introduced 10 c.c. of sterile Ashby's mannite solution and the surface of the slant scratched with a sterile Pt. needle so as to obtain uniform suspension of the organisms in mannite solution. One hundred c.c. of Ashby's mannite solution kept in 250 c.c. flasks were inoculated in triplicates with one c.c. of the suspension and incubated at 30°C. for a fortnight. At the end of the period, the contents of the flasks were digested with concentrated H_2SO_4 for estimation of nitrogen by Kjeldahl's method.

Results

The morphological, cultural and biochemical characteristics of the organisms isolated from tank silts are detailed in Table I.

Table I

Morphological, cultural and biochemical characteristics of the organisms

Characteristics	Habitat		
	Aurangabad	Beldanga	Diamond Harbour
Morphological	Slowly motile short oval rods, 3·2μ-1·6μ, occurring most often in pairs, gram negative, non-capsulated, no spores.	Motile plump rods, almost coccoid, 2·7μ-2·3μ, occurring in pairs, gram negative, non-capsulated, no spores.	Non-motile short oval rods, 2·2μ-1·6μ, occurring in pairs, gram negative, non-capsulated, no spores.
Cultural	Form deep black scum in mannite solution, brown pigment on mannite agar, growth on potato-scarcely visible, slimy, turning brown, no growth on gelatine.	Form black scum in mannite solution, brown pigment on mannite agar, growth on potato-copious, slimy pale yellow, no growth on gelatine.	Form brown scum in mannite solution, brown pigment on mannite agar, growth on potato-scant, barely visible, slimy, shining, no growth on gelatine.

TABLE I—*(contd.)*

Morphological, cultural and biochemical characteristics of the organisms

Characteristics	Habitat		
	Aurangabad	Beldanga	Diamond Harbour
Biochemical			
Glucose	+	+	+
Dextrose	+	+	+
Lactose	+	+	+
Mannitol	+	+	+
Sucrose	+	+	+
Nutrient broth	—	+	—
Glucose-peptone broth	—	+	—
Dextrose-peptone broth	—	+	—
Lactose-peptone broth	—	+	—
Sucrose-peptone broth	—	+	—
Milk	—	—	—
Litmus milk	—	—	—
Nitrate reduction	—	—	—
Ammonia formation	—	—	—
Indole production	—	—	—
H_2S production	—	—	—
Hydrolysis of starch	—	—	—
Liquefaction of gelatine	—	—	—

Characteristics	Ghatal	Ghorsala	Gidni
Morphological	Non-motile short oval rods, 2·9μ-1·8μ, occurring most often in pairs, gram negative, capsulated, no spores.	Slowly motile oval rods, 0·8μ-0·4μ, occurring in pairs, capsulated, gram negative, no spores.	Non-motile short oval rods, 3·4μ-1·8μ, occurring in pairs, gram negative, no spores.
Cultural	Form deep black scum in mannite solution, black pigment on mannite agar, growth on potato-barely visible, shining, turning chocolate, no growth on gelatine.	Form a white scum in mannite solution, no pigment on mannite growth on potato-barely visible, glossy turning brown, no growth on gelatine.	Form a white scum in mannite solution, no pigment on mannite agar, growth on potato barely visible, shining slimy, no growth on gelatine.
Biochemical			
Glucose	+	+	+
Dextrose	+	+	+
Lactose	+	+	+
Mannitol	+	+	+
Sucrose	+	+	+
Nutrient broth	—	—	—
Glucose-peptone broth	—	—	—

TABLE I—(*contd.*)

Morphological, cultural and biochemical characteristics of the organisms

Characteristics	Ghatal	Ghorsala	Gidni
Dextrose-peptone broth	—	—	—
Lactose-peptone broth	—	—	—
Sucrose-nutrient broth	—	—	—
Milk	—	—	Slight clearing after ten days
Litmus milk	—	—	Slight clearing after ten days but no decolourisation
Nitrate reduction	—	—	—
Ammonia formation	—	—	—
Indole formation	—	—	—
H_2S production	—	—	—
Hydrolysis of starch	—	—	—
Liquefaction of gelatine	—	—	—

Characteristics	Jangipur 532	Jangipur 534	Kalyanpur
Morphological	Non-motile short oval rods, 2·4μ-1·5μ occurring single and in pairs, gram negative, capsulated, no spores.	Non-motile short oval rods, 2·6μ-1·6μ occurring in pairs, gram negative, non-capsulated, no spores.	Slowly motile short oval rods, 2·2μ-1·6μ occurring mostly in pairs, gram negative, non-capsulated, no spores.
Cultural	Form a white scum in mannite solution, black pigment on mannite agar, growth on potato-copious slimy, creamy white, on gelatine-yellowish small circular colonies.	Form a white scum in mannite solution, greyish pigment on mannite agar, growth on potato-barely visible, slimy, turning brown, on gelatine-no growth.	Form a white scum in mannite solution, black pigment on mannite agar growth on potato-copious greyish white, on gelatine-yellowish small circular colonies.
Biochemical			
Glucose	+	+	+
Dextrose	+	+	+
Lactose	+	+	+
Mannitol	+	+	+
Sucrose	+	+	+
Nutrient broth	+	—	+
Glucose-peptone broth	+	—	+
Dextrose-peptone broth	+	—	+
Lactose-peptone broth	+	—	+
Sucrose-peptone broth	+	—	+
Milk	—	—	Slight clearing after ten days
Litmus milk	—	—	Slight clearing after ten days but no decolorisation
Nitrate reduction]	—	—	—
Ammonia formation	—	—	—

TABLE I—(*contd.*)

Morphological, cultural and biochemical characteristics of the organisms

Characteristics	Jangipur 532	Jangipur 534	Kalyanpur
Indole formation	—	—	—
H_2S production	—	—	—
Hydrolysis of starch	—	—	—
Liquefaction of gelatine	—	—	—

Characteristics	Khairagola	Khirapai	Khirasagar
Morphological	Motile oval short rods, almost coccoids, 1·9μ-1·4μ, occurring most often in pairs, gram negative, capsulated, no spores.	Non-motile short oval rods, 2·4μ-1·5μ, occurring in pairs, gram negative, capsulated, no spores.	Non-motile short oval rods, 0·8μ-0·4μ, occurring in pairs and sometimes in chains of three, gram negative, non-capsulated, no spores.
Cultural —	Form white scum in mannite solution, black pigment on mannite agar, growth on potato-copious, slimy, cream colour, no growth on nutrient gelatine.	Form brown scum in mannite solution, brown pigment on mannite agar, growth on potato-copious, slimy, whitish, gelatine colonies-small, circular and yellowish.	Form a white scum in mannite solution, no pigment on mannite agar, growth on potato-copious, slimy whitish, grey, gelatine colonies-small, circular and brownish.
Biochemical			
Glucose	+	+	+
Dextrose	+	+	+
Lactose	+	+	+
Mannitol	+	+	+
Sucrose	+	+	+
Nutrient broth	+	+	+
Glucose-peptone broth	+	+	+
Dextrose-peptone broth	+	+	+
Lactose-peptone broth	+	+	+
Sucrose-peptone broth	+	+	+
Milk	—	Slight clearing after ten days	
Litmus milk	—	Slight clearing after ten days but no decolorisation	
Nitrate reduction	Doubtful	—	—
Ammonia formation	—	—	—
Indole formation	—	—	—
H_2S production	—	—	—
Hydrolysis of starch	—	—	—
Liquefaction of gelatine	—	—	—

Characteristics	Kulpi	Maldah	Nayagram
Morphological	Non-motile short oval rods, 3·8μ-2·6μ, occurring single and in pairs, gram negative, capsulated, no spores.	Motile short oval rods, almost coccoid, 1·8μ-1·5μ occuring single and in pairs, gram negative, non-capsulated, no spores.	Non-motile short oval rods, 2·0μ-1·4μ, occurring in pairs, gram negative, capsulated, no spores.

TABLE I—(*contd.*)

Morphological, cultural and biochemical characteristics of the organisms

Characteristics	Kulpi	Maldah	Nayagram
Cultural	Form black scum in mannite solution, black pigment on mannite agar, growth on potato-copious, slimy, dirty grey, gelatine colonies small, circular and yellowish.	Form black scum in mannite solution, black pigment on mannite agar, growth on potato-copious, slimy, yellowish gelatine colonies small, circular and yellowish.	Form white scum in mannite solution, no pigment on mannite agar, growth on potato-poor, hardly visible, slimy, turning brown no growth on gelatine.
Biochemical			
Glucose	+	+	+
Dextrose	+	+	+
Lactose	+	+	+
Mannitol	+	+	+
Sucrose	+	+	+
Nutrient broth	+	+	—
Glucose-peptone broth	+	+	—
Dextrose-peptone broth	+	+	—
Lactose-peptone broth	+	+	—
Sucrose-peptone broth	+	+	—
Milk	—	Slight clearing after ten days	—
Litmus milk	—	Slight clearing after ten days but no decolorisation	—
Nitrate reduction	—	—	—
Ammonia formation	—	—	—
Indole formation	—	—	—
H. S. production	—	—	—
Hydrolysis of starch	—	—	—
Liquefaction of gelatine	—	—	—

Characteristics	Noada	Rajnagar	Sirshia
Morphological	Slowly motile oval rods, 0·7μ-0·4μ, occurring mostly in pairs, gram negative, non-capsulated, no spores.	Motile short oval rods, 2·4μ-1·7μ, occurring mostly in pairs, gram negative, non-capsulated, no spores.	Slowly motile short oval, rods, 1·9μ-0·9μ, occurring mostly in pairs, gram negative, non-capsulated, no spores.
Cultural	Form a grey scum in mannite solution, no pigment on mannite agar, growth on potato-copious, slimy, creamy colour, gelatine colonies-small, circular and yellowish.	Form a white scum in mannite solution, no pigment on mannite agar, growth on potato-copious, slimy, dirty white in colour, gelatine colonies small, circular and yellowish.	Form a black scum in mannite solution, no pigment on mannite agar, growth on potato-barely visible, slimy turning black, no growth on nutrient gelatine.
Biochemical			
Glucose	+	+	+
Dextrose	+	+	+

TABLE I—(*contd.*)

. Morphological, cultural and biochemical characteristics of the organisms

Characteristics	Noada	Rajnagar	Sirshia
Lactose	+	+	+
Mannitol	+	+	+
Sucrose	+	+	+
Nutrient broth	+	+	—
Glucose-peptone broth	+	+	—
Dextrose-peptone broth	+	+	—
Lactose-peptone broth	+	+	—
Sucrose-peptone broth	+	+	—
Milk	Slight clearing after ten days	Slight clearing after ten days	—
Litmus milk	Slight clearing after ten days but no change in colour	Slight clearing after ten days but no change in colour	—
Nitrate reduction	—	—	—
Ammonia formation	—	—	—
Indole formation	—	—	—
H_2S production	—	—	—
Hydrolysis of starch	—	—	—
Liquefaction of gelatine	—	—	—

Characteristics	Sonarpur	Suri
Morphological	Non-motile oval rods, 3·5μ-2·3μ, occurring single and in pairs, gram negative, capsulated, no spores.	Non-motile short oval rods 1·2μ-0·9μ, occurring in pairs, gram negative, non-capsulated, no spores.
Cultural	Form a white scum in mannite solution, black pigment on mannite agar, growth on potato barely visible, slimy, turning chocolate colour, no growth on nutrient gelatine.	Form a black scum in mannite solution, faint brown pigment on mannite agar, growth on potato barely visible, slimy, turning brown, no growth on nutrient gelatine.
Biochemical		
Glucose	+	+
Dextrose	+	+
Lactose	+	+
Mannitol	+	+
Sucrose	+	+
Nutrient broth	—	—
Glucose-peptone broth	—	—
Dextrose-peptone broth	—	—
Lactose peptone broth	—	—
Sucrose-peptone broth	—	—
Milk	—	—

TABLE I—(*contd.*)

Morphological, cultural and biochemical characteristics of the organisms

Characteristics	Sonarpur	Suri
Litmus milk	—	—
Nitrate reduction	—	—
Ammonia formation	—	—
Indole formation	—	—
H_2S production	—	—
Hydrolysis of starch	—	—
Liquefaction of gelatine	—	—

—no growth, negative; +growth, positive.

It is evident from the observations in Table I that the organisms were *Azotobacter* of one species or other [Bergey, 1948].

Average amounts of nitrogen fixed in Ashby's solution per gram of manuite by the mixed flora and by *Azotobacter* isolated from tank silts, during a period of two weeks are given in Table II. It will be observed that in most of the cases the mixed flora caused more fixation of nitrogen than the pure strains of *Azotobacter*.

TABLE II

Fixation of nitrogen by the mixed flora and Azotobacter *from tank silts (mg. per gm. of mannite during two weeks)*

Tank silt	Mixed flora	*Azotobacter*
Aurangabad	10·5 (11·4 ; 10·6 ; 9·8)	2·7 (4·2 ; 2·0 ; 2·2)
Beldanga	9·2 (8·9 ; 9·1 ; 9·5)	6·1 (8·6 ; 4·3 ; 5·3)
Diamond Harbour	9·9 (9·3 ; 9·8 ; 10·4)	7·4 (9·1 ; 10·0 ; 4·2)
Ghatal	10·0 (8·3 ; 10·1 ; 11·7)	3·2 (4·0 ; 1·6 ; 4·0)
Ghorsala	5·7 (5·8 ; 5·8 ; 5·6)	2·7 (2·8 ; 2·3 ; 2·9)
Gidni	6·1 (6·1 ; 6·0 ; 6·1)	2·0 (2·2 ; 1·8 ; 2·0)
Jangipur 532	6·0 (6·6 ; 6·1 ; 5·4)	3·3 (2·2 ; 2·4 ; 5·2)
Jangipur 534	5·7 (5·6 ; 5·8 ; 5·8)	2·1 (2·2 ; 2·0 ; 2·2)
Kalyanpur	11·0 (11·2 ; 11·1 ; 10·8)	4·3 (3·2 ; 5·4 ; 4·3)
Khirapai	5·5 (4·9 ; 5·6 ; 6·1)	2·8 (4·6 ; 1·8 ; 2·0)
Khairagola	7·6 (8·2 ; 7·7 ; 7·0)	5·9 (5·6 ; 3·6 ; 8·4)
Khirasagar	5·8 (5·3 ; 5·7 ; 6·3)	2·0 (2·2 ; 1·8 ; 2·0)
Kulpi	7·7 (7·4 ; 7·6 ; 8·1)	4·4 (4·6 ; 4·4 ; 4·3)
Maldah	9·5 (10·1 ; 9·6 ; 8·9)	2·8 (2·4 ; 3·4 ; 2·5)
Nayagram	7·6 (7·4 ; 7·5 ; 7·8)	2·0 (2·2 ; 1·8 ; 2·1)
Noada	9·0 (8·6 ; 9·1 ; 9·4)	2·0 (2·6 ; 2·8 ; 1·6)
Rajnagar	4·4 (5·3 ; 4·5 ; 3·5)	4·7 (6·0 ; 3·8 ; 4·4)
Sirshia	13·7 (11·9 ; 13·8 ; 15·5)	2·1 (2·4 ; 2·8 ; 1·2)
Sonarpur	6·9 (6·2 ; 7·0 ; 7·6)	4·3 (4·7 ; 4·3 ; 3·8)
Suri	7·7 (6·3 ; 7·8 ; 9·1)	2·3 (2·4 ; 1·6 ; 2·5)

The figures of nitrogen quoted are after deduction of blanks. Figures within brackets are results of individual determinations.

Discussion of Results

It is evident from Table I that the organisms differ in size ; on average, most of them appear to be smaller than what is recorded for different species of *Azotobacter*. They also differ in motility. Almost half of them form pigments in pure cultures and the rest do not do so. Pigment formation, however, appears to depend on the conditions to which these organisms are subjected. Organisms from Jangipur 532 which form black pigment on mannite agar, produce a white scum in mannite solution. Organisms from Noada and Sirshia do not form pigments in mannite but do so in Ashby's solution. It can be seen from the data in Tables I and II that pigment forming organisms (on mannite agar) generally fix more nitrogen than the organisms which do not form pigments. The difference in the nature of the organisms from two different tanks in the same locality Jangipur can be observed in their pigment forming capacities and capacities for nitrogen fixation. There seems to be no relationship between motility of the organisms and their nitrogen fixing capacities.

Nitrogen fixation, in the case of tank silts studied, varied from 2·0 to 7·4 mg. per gram of mannite during a period of two weeks, when pure strains of *Azotobacter* are used (Table II). This is of the same order as is observed in the case of *Azotobacter* isolated from common agricultural soils. Nitrogen fixation by the mixed flora is very much higher than the same by the pure strains of *Azotobacter*. This has also been observed in the case of soils, among others by Bhaskaran and Pillai [1939, 1942] who attributed much of the fixation to more efficient utilisation of anaerobic decomposition products of carbohydrates by the mixed flora than of the undecomposed carbohydrate itself.

Summary and Conclusions

Pure strains of *Azotobacter* were isolated from air-dried tank silts collected from 19 villages in West Bengal. The *p*H value of the silts varied from 4·8 to 7·2.

Average fixation of nitrogen during a period of two weeks by the organisms varied from 2·0 to 7·4 mg. per gram of mannite. Fixation of nitrogen by the mixed flora was generally higher than that by the pure strains of *Azotobacter*.

Acknowledgment

Some of the data presented in this article have been taken from a paper read at the 41st session of the Indian Science Congress an abstract of which appeared in the proceedings of the same.

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APPENDIX I

Composition of the tank silts

Constituents expressed as per cent on oven dry basis

Locality	Hygroscopic moisture	*p*H	CaO	P_2O_5
Aurangabad	2·31	7·2	1·29	0·37
Beldanga	4·50	5·7	0·35	0·23
Diamond Harbour	3·98	6·7	1·23	0·23
Ghatal	2·44	6·9	0·41	0·12
Ghorsala	13·37	5·7	·39	0·17
Gidni	6·04	5·0	·27	0·02
Jangipur 532	4·80	6·9	·29	0·12
Jangipur 534	3·24	7·2	1·70	0·03
Kalyanpur	9·71	6·6	1·12	0·21
Khairagola	1·60	6·2	0·31	0·11
Khirapai	1·41	5·5	·31	0·15
Khirasagar	3·24	5·2	·32	0·36
Kulpi	4·12	5·2	·12	0·23
Maldah	4·45	5·2	·23	0·19
Nayagram	2·82	5·1	·20	0·06
Noada	2·44	7·6	3·07	0·13
Rajnagar	4·59	4·8	0·53	0·12
Sirshia	6·58	6·4	1·32	0·28
Sonarpur	3·27	6·7	0·52	0·02
Suri	6·56	6·6	2·19	0·28

SYSTEMATICS OF ORIENTAL TERMITES

II. A NEW SPECIES, *COPTOTERMES GAURII*, FROM CEYLON*

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(With two text figures and three appendices)

Jepson [1930 *a*, *b*] referred to a new species from Ceylon, namely, *Coptotermes exiguus* (Isoptora, Rhinotermitidae,) which was identified for him by the late Mr. N. A. Kemner of Lund (Sweden), but no description was ever published and the name *exiguus* remains a manuscript name of Kemner [also *vide* Snyder, 1949]. Ratanlal and Menon [1953] have erroneously referred the name *exiguus* to Hagen who never described a Ceylon *Coptotermes* under that name (also *vide infra* under Invalid Names and under Remarks). This new Ceylon species, which is described below, has often been confused with *Coptotermes ceylonicus* Holmgren, as is evident by a vial in this Institute's collection determined as *ceylonicus* Holmgr but which actually proved to be the new species.

Description

Family : Rhinotermitidae

Sub-family : Coptotermitinae

Genus : *Coptotermes* Wasmann

Coptotermes gaurii Roonwal and Krishna (sp. nov.)

(*a*) *Invalid names, etc.*

The following invalid names or misidentifications for the new species, *Coptotermes gaurii* R. and K., are available in the literature :

1930. *Coptotermes exiguus*, Jepson, *Trop., agric.* Peradeniya, **75**(3), 155. *Nom. nud.* (Ceylon)

1930. *Coptotermes exiguus*, Jepson, *Tech. Rep. Dept. Agric. Ceyion*, 1929, Colombo, p. 6. *Nom. nud.* (Ceylon)

1949. *Coptotermes exiguus* Kemner (MS. name), *vide* Snyder, *Smiths. Misc. Coll.*, Washington, **112**, p. 346 . (Ceylon) [Not *Termes* (*Eutermes*) *exiguus* Hagen 1858, Central and S. America]

1953. *Coptotermes exiguus* (Hagen), Ratanlal and Menon, *Catal. Indian Insects, Pt. 27, Isopt.*, New Delhi, p. 25. Wrong identification (see note below). Ceylon.

1953. *Eutermes exiguus Desneux*, Ratanlal and Menon, *Catal. Indian Insects, Pt. 27, Isopt.*, New Delhi, p. 25. Wrong identification (see note below) Ceylon.

1953. *Coptotermes ceylonicus* Holmgren, Roonwal and Pant, *Indian For. Leafl.* (*Ent.*), Delhi, No. 121 (3), p. 47. Ceylon (specimens from 'Marambekenda, 400 ft.' only).

1953. *Coptotermes exiguus* Kemner, Roonwal and Pant, *Indian For. Leafl.* (*Ent.*), Delhi, No. 121(3), p. 47. *Nom. nud.* (Ceylon)

*This work was carried out under the Termite Research Scheme (Taxonomy), financed by the Indian Council of Agricultural Research.

(*b*) *Material*

Two lots, present in the Entomological Collection of the Forest Research Institute, Dehra Dun, are as given below :

Lot 1. One spirit vial, No. M.C.* 17450, in the Main Collection. Three soldiers and *ca.* 13 workers from 'Ceylon', all shrivelled up ; also 2 soldiers on card from the same lot. Collected and donated by *J. Hutson* (his No. 7267) who was Entomologist to the Ceylon Department of Agriculture, Peradeniya, Ceylon. Date of collection not known, but received in Forest Research Institute on 10th April 1940, under Hutson's letter No. 761, dated 3rd April, 1940. *Det.* as *'Coptotermes exiguus'* by Hutson.

Lot 2. (i) One spirit vial, No. M.C.* 17428, in the Main Collection. Several soldiers and 4 workers. Collected by *Gauri Dutt* (his No. 170), 31st December 1934, Marambekenda, Ceylon, 400 ft. above sea-level ; *ex.* unknown rotten wood. *Det.* as *Coptotermes ceylonicus* by J. C. M. Gardner. (ii) Three slides from the same lot, thus : Slide No. 142, body-parts of soldier ; No. 143, body-parts of worker ; No. 144, 2 whole soldiers and 1 worker head. The spirit vial now divided into 2 vials, No. M.C. 17428/1 and 17428/2

(*c*) *Description*

1. Imago. Unknown.

2. Soldier. *General* : Head light yellow ; mandibles brown ; yellowish at the base ; antennae, pronotum, legs and abdomen pale yellow, paler than head. Head with a few erect, scattered hairs ; two small bristles on either side of fontanelle ; pronotum with a few very small setae-like hairs at the anterior margin, with long hairs along its anterior, posterior and lateral margins, and with a few hairs scattered on the disc ; terga densely pilose, the hairs not arranged in rows but scattered irregularly.

Head : Pear-shaped, only slightly longer than broad ; sides rounded up to the margins of antennal Foveolae, thence straight and gradually converging in front ; posterior margin rounded. Frontal gland area paler than rest of head-capsule. *Fontanelle* : Prominent, tubular, with a heavy chitinous border ; projecting in front as far as the anterior angles of the head-capsule ; fontanelle aperture circular. *Antennae* : Pilose, 14-jointed, 1st joint cylindrical, longest ; 2nd also cylindrical, half as long as the 1st ; 3rd shorter than 2nd and 4th ; 4th shorter than 2nd ; 5th-13th pear-shaped, pedunculate, subequal ; terminal (14th) joint ovate, narrower than preceding joints. *Eyes* : Absent. *Labrum* : Subtriangular, longer than broad ; basally, the sides subparallel, distally converging into a long, roundly truncated apex ; apex hyaline with two long bristles. *Clypeus* : Short, trapezoidal, broader than long ; not divided into ante and postclypeus.

* M. C. stands for ' Main Collection '.

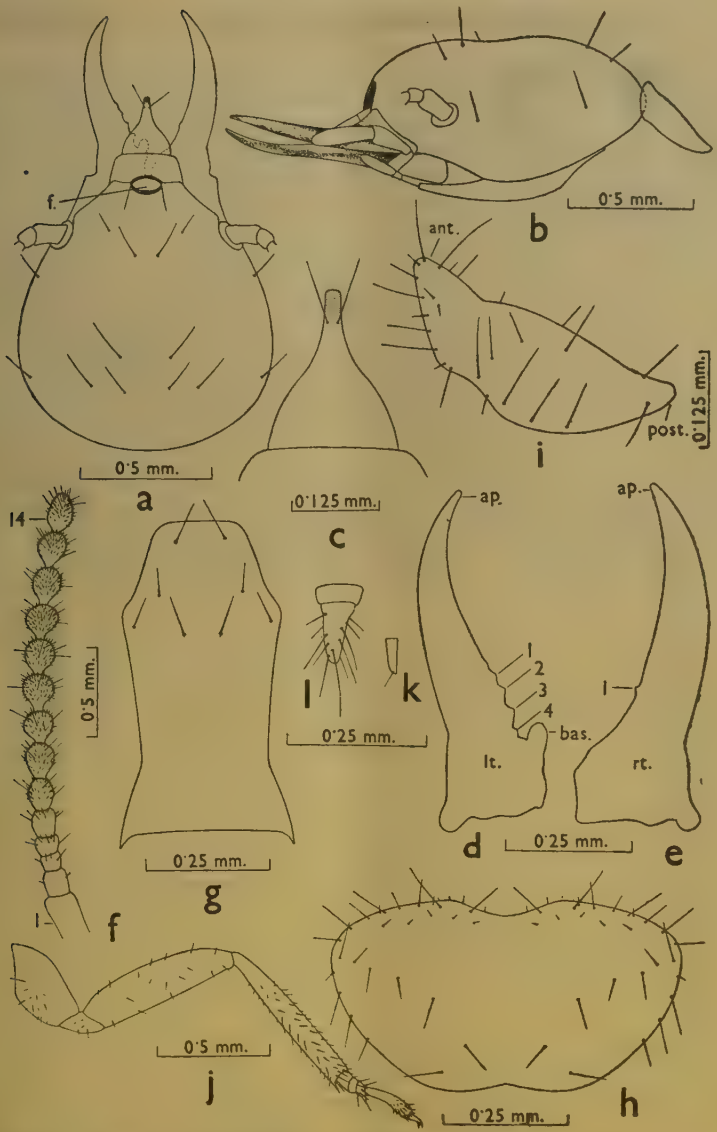

Fig. 1.—*Coptotermes gaurii* Roonwal and Krishna (sp. nov.). Soldier caste.
(*a*) Head-capsule, in dorsal view. (*b*) Head-capsule and pronotum, in side view. (*c*) Labrum, in dorsal view. (*d*) Left mandible, in dorsal view. Marginal teeth numbered. (*e*) Ditto, right mandible. (*f* Antenna. First and last (14th) segments numbered. (*g*) Postmentum, in dorsal view. (*h*) Pronotum, in dorsal view, as mounted on a slide. (*i*) Pronotum, in side view (left), *in situ*. (*j*) Hind-leg. (*k*) Stylus, on 9th abdoninal sternum. (*l*) Cercus, on 10th abdominal sternum.
ant., anterior; *ap.*, apical tooth of mandible; *bas.*, basal tooth of mandible; *f.*, fontanelle; *lt.*, left.; *post.*, posterior; *rt.*, right.

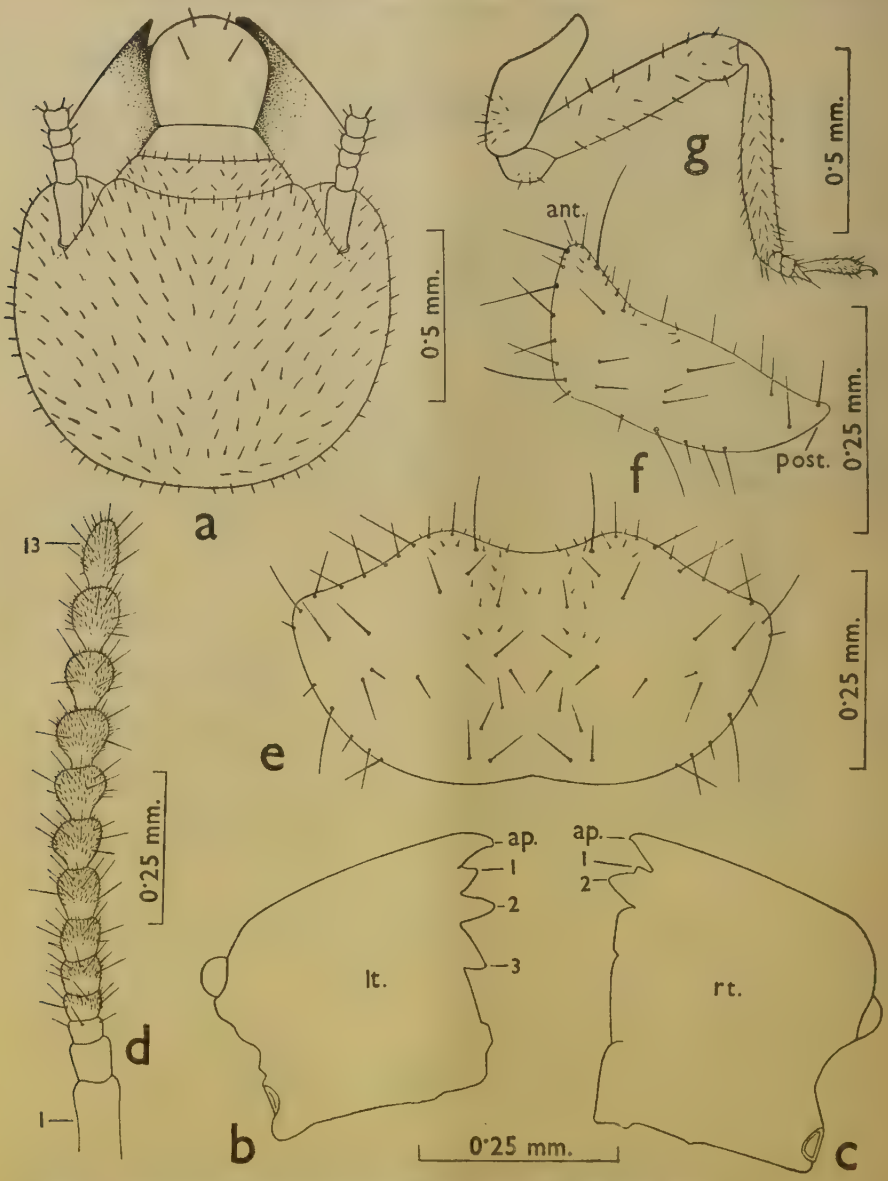

FIG. 2.—*Coptotermes gaurii* Roonwal and Krishna (sp. nov.). Worker caste.

(*a*) Head-capsule, in dorsal view. (*b*) Left mandible, in dorsal view. Marginal teeth numbered. (*c*) Ditto, right mandible. (*d*) Antenna. (First and last segments numbered.) (*e*) Pronotum, in dorsal view (as mounted flat on a slide). (*f*) Pronotum in side view (left), *in situ*. (*g*) Hind-leg.

ap., apical tooth of mandible ; *ant.*, anterior ; *lt.*, left ; *post.*, posterior : *rt.*, right.

Mandibles : Sabre-shaped, broad at base, narrow, rather sharp-pointed and slightly incurved at apex. Left mandible : Distal half of inner margin smooth ; proximal half with a large basal tooth and 4 crenulations, the 4th very small ; in some individuals an extremely small projection anterior to the 1st present, suggesting a tooth. Right mandible : Inner margin smooth except for basal area which is slightly wavy and has a microscopic tooth visible under high magnification. *Postmentum* : Shorter than head, with a bulge in anterior one-third whence the sides gradually slope in and then out ; with only a small constriction in the middle ; anterior margin straight, posterior margin concave.

Thorax : *Pronotum* : Much narrower than head and markedly wider than long ; anterior margin convex, with a deep median notch ; sides roundly sloping posteriorly ; posterior margin with a shallow notch in the middle. *Legs* : Femur long, with a few scattered hairs ; tibia slender, with several spines about as long as the spurs on distal inner edges ; hind-tibia longest ; 3 tibial spurs in fore-leg, 2 in middle-leg and 2 in hind-leg.

Abdomen : Heavily pilose, with hairs scattered irregularly and not in rows. Styli very small, unsegmented 0·07 mm. long ; present on posterior margin of 9th sternum ; very close to each other. Cerci on 10th sternum ; 2-segmented, hairy, 0·14 mm. long ; basal joint ring-shaped ; 2nd long and finger-shaped 0·092 mm. long and with 2 or 3 long hairs at the tip.

Measurements : See Appendix I.

3. Worker. *General* : Head yellowish, mandibles pale yellow, except the toothed edges which are dark brown ; antennae and legs pale yellow, paler than head ; abdomen dirty white. Head fairly thickly pilose, with short-hairs ; pronotum thickly pilose ; abdomen densely hairy, with hairs scattered irregularly and not arranged in rows.

Head : Broader than long, sub-circular ; epicranial suture not visible. *Fontanelle* : Absent. *Antennae* : Pilose, 13-15 jointed ; 2nd joint cylindrical, equal to 3rd plus 4th ; 3rd and 4th small, subequal, broader than long ; 5th to penultimate, pearshaped, weakly pedunculate ; terminal joint ovate, narrower than preceeding joints. *Eyes* : Absent. *Labrum* : Broader than long, sides sub-parallel, distal end rounded. *Clypeus* : Divided into ante-and postclypeus. *Mandibles* : Of typical *Coptotermes* type. Left mandible with 1 apical and 3 marginal teeth ; 1st marginal smallest. Right mandible with 1 apical and 2 marginal teeth ; 1st marginal greatly reduced.

Thorax : *Pronotum* : Broader than long ; anterior margin well projected in front, with a deep, obtuse median incission ; sides roundly sloping posteriorly ; posterior margin rounded and shallowly incised in middle. *Legs* : As in soldier.

Abdomen : Heavily pilose, hairs scattered irregularly. Cerci and styli as in soldier.

Measurements : See Appendix II.

(*d*) *Type-specimens*

1. *Holotype and morphotype.* A holotype soldier and a morphotype worker in a single vial, in spirit, deposited in the Entomological Collection of the Forest Research Institute, Dehra Dun. Coll. *Gauri Dutt*, 31. xii. 1934, Marambekenda, Ceylon, 400 ft. For measurements of holotype soldier see Appendix I ; the holotype has the right fore-leg and middle-leg damaged.

2. *Paratypes and paramorphotypes.*—From holotype lot and with same collection data, deposited as follows : (i) In Forest Research Institute, Dehra Dun : One vial with several paratype soldiers and 3 paramorphotype workers. Also 3 slides, Nos. 142, 143, 144, as mentioned above under 'Material'. (ii) With Prof. Alfred E. Emerson, Zoology Department, Chicago University, Chicago, U.S.A. : One soldier, in spirit.

(*e*) *Type-locality and type-host*

Merambekanda, Ceylon, 400 feet above sea-level. *Ex.* rotten wood of unknown species.

(*f*) *Geographical distribution*

Ceylon : Marambekanda, 400 ft. (*vide supra*) ; also the following localities as given by Jepson (1930*a*) : Arissawella, Galaha, Kiriella, Peradeniya and Ratanpura all in Ceylon.

(*g*) *Hosts*

Living plants of tea, *Camellia sinensis* (Linn.) O. Kuntze (syn. *C. thea* Link. and *C. theifera* Griff.), being a serious pest of it, boring into stem and roots (Jepson, 1930*a*) ; living plants of the Malayan dadap, *Erythrina lithosperma* Bl. ex. Miq. (Family Leguminosae) [Ratan Lal and Menon, 1953] ; a potential pest of the pará rubber plant, *Hevea brasiliensis* Muell. Arg., though not actually recorded on it (Jepson 1930*a*) ; also on logs and other articles of wood in contact with the soil.

(*h*) *Comparisons.* See Appendix III.

Coptotermes gaurii sp. nov. is, along with *C. kalshoveni* Kemner, the smallest of the oriental representatives of the genus *Coptotermes*. It is quite close to *Coptotermes ceylonicus* Holmgren (from Ceylon), *C. kalshoveni* Kemner (from Java) and *C. minutissimus* Kemner (from Bera Massidi Is. between Muna Is. and S.E. tip of Celebes, Indonesia), but differs in the particulars mentioned in Appendix III. Its closest relative appears to be *kalshoveni* Kemner.

It may be added that four species of *Coptotermes* are now known to occur in Ceylon, viz.

1. *C. ceylonicus* Holmgren.
2. *C. emersoni* Ahmad (*Spol. Zeyl.*, **27**, p. 37, 1953).
3. *C. formosanus* Shiraki. (Introduced in Ceylon, *vide* Ahmad, *Spol. Zeyl.*, 27, p. 35-36, 1953).
4. *C. gaurii* Roonwal and Krishna, sp. nov. (present account)

(*i*) *Remarks*

The invalid names and misidentifications of this species have already been summarised above. A word is, however, necessary regarding the confusion which has been caused by Ratanlal and Menon [1953,] by their unjustified mixing up of *exiguus* Hagen and *exiguus* Kemner (manuscript name). By including this species under the genus *Coptotermes*, by quoting Jepson's references [1930 *a*, *b*], and by giving the locality as Ceylon, Ratanlal and Menon leave little doubt that they have *Coptotermes exiguus* Kemner (MS. name) (here described as *gaurii* R. & K.) in mind (also *cf.* Snyder, 1949). They, however, assign the authorship of *exiguus* to Hagen [1858 p. 203] who described *Termes eutermes exguus* (now referred to genus *Microcerotermes*, *vide* Snyder, 1949, p. 138) from Central and South America; Hagen never described an *exiguus* from Ceylon, nor one referable to the genus *Coptotermes*. Again, Ratanlal and Menon's synonymy quoted as '*Eutermes exiguus* Desneux', really refers to Hagen's species which Desneux [1904, p. 42] gave as '*Termes* (*Eutermes*) *exiguus* Hagen', and whose locality be clearly mentioned as Amazon, Brazil.

SUMMARY

1. A new species, *Coptotermes gaurii* Roonwal and Krishna, is described from Ceylon. It has been referred to in the literature as *C. exiguus* Kemner (a manuscript name or a *nomen nudum*).

2. The soldier and workers are described. The imago is unknown.

3. *Type-locality :* Merambekenda, Ceylon, 400 ft. *Type-host :* Rotten wood of unknown species. The species is confined to Ceylon.

4. The new species is close to following species of *Coptotermes* with which it is compared :—*Ceylonicus* Holmgr., *minutissimus* Kemner and *kalshoveni* Kemner ; it appears to be closest to the last mentioned species.

5. *C. gaurii* is a serious pest of tea bushes and a potential pest of the rubber plant, *Hevea brasiliensis* ; also a pest of *Erythrina lithosperma* plants.

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APPENDIX I

Body measurements, etc. (in mm.) of soldiers of Coptotermes gaurii *Roonwal and Krishna (sp. nov.).*

Item	No. of specimens	Range	Holotype (soldier)
GENERAL			
1. Total body-length (approximate)	10	3·08—3·65	3·65
HEAD			
2. Length of head to lateral base of mandible	10	1·03—1·08	1·08
3. Max. width of head	10	0·91—1·03	1·00
4. Height of head (No. 1)	10	0·69—0·77	..
5. Occiput-fontanelle distance (No. 1)	10	1·03—1·08	1·08
6. Length of labrum	6	0·23	0·23
7. Width of labrum	6	0·17	0·17
8. Max. length of mandibles			
(*a*) Right mandible	10	0·57—0·63	0·63
(*b*) Left mandible	10	0·57—0·63	0·63
9. Number of antennal segments	5	14	14
10. Minimum (median) length of postmentum	10	0·57—0·63	0·63
11. Maximum width of postmentum	10	0·29—0·34	0·34
12. Minimum width of postmentum	10	0·23—0·29	0·29
THORAX			
13. Maximum length of pronotum	10	0·37—0·40	4·00
14. Maximum width of pronotum	10	0·57—0·68	0·68
15. Length of hind-femur	6	0·70—0·71	0·75
16. Width of hind-femur	7	0·14—0·23	0·17
ABDOMEN			
17. Length of stylus	1	*ca.* 0·07	..
18. Length of cercus	1	*ca.* 0·14	..

APPENDIX II

Body measurements (in mm.) etc. of workers of Coptotermes gaurii *Roonwal and Krishna (sp. nov.).*

Item	No. of specimens	Range
1. Total body-length (approximate)	2	2·74—2·91
2. Length of head to lateral base of mandibles	2	0·91
3. Max. width of head	2	1·03
4. Length of labrum	2	0·29—0·34
5. Width of labrum	1	0·34
6. Min. length of mandibles		
(*a*) Right mandible	2	0·40
(*b*) Left mandible	2	0·40
7. Number of antennal segments	3	13—15
8. Max. length of pronotum	2	0·29
9. Max. width of pronotum	2	0·51—0·57
10. Length of hind-femur	2	0·68
11. Width of hind-femur	2	0·18
12. Number of segments of cerci (including basal plate)	1	2

APPENDIX III

Comparison of Coptotermes gaurii *Roonwal and Krishna (sp. nov.) with other closely allied species of the genus* Coptotermes. *Soldier caste.*

Item	*gaurii* Roonwal and Krishna (sp. nov.)	*kalhoreni* Kemner	*minutissimus* Kemner	*ceylonicus* Holmgren
1. Body-length	Small (3·08—3·65 mm.)	Small (about the same as *gaurii*), 3·55—3·65 mm.	Larger than *gaurii*, 3·65—4·00 mm.	Larger (4·22—4·79 m.)
2. Head-capsule	Smaller; very narrow in front more swollen (less flat)	Size as in *gaurii*; less narrow in front ;less swollen (more flat)	Somewhat larger than *gaurii* less narrow in front; less swollen (more flat).	Larger ; less narrow infront; less swollen (more flat)
3. Head Index (Width/Length)	Larger, 0·898	?	?	Smaller, 0·818
4. Mandibles	Length 0·57—0·63 mm.; slender	Shorter and more robust	?	Longer (0·741—0·798 mm.); and more robust
5. Antennae	14-jointed. 2nd joint longer than 3rd and 4th 4th longer than 3rd	13-14 jointed. 2nd joint twice the length of 3rd ; 4th longer than 3rd and rounded	13-jointed. 2nd joint longer than 3rd; 4th longer than 3rd and as long as 2nd.	14-15-jointed 2nd joint only slightly longer than 3rd and 4th; 4th slightly longer than 3rd
6. Postmentum	Shorter in length; less contracted in middle	As in *gaurii*	As in *gaurii*.	Longer; more contracted in middle
7. Pronotum	Less wide (0·57—0·68 mm.); longer (0·34—0·4 mm.)	Width as in *gaurii* (0·58—0·60 mm.); shorter in length (0·31 mm.)	Width as in *gaurii* (0·59—0·63 mm.); shorter in length (0·31—0·35 mm.)	Wider (0·8—0·87 mm.); longer (0·38—0·42 mm.)
8. Hairs on abdominal tergites	Scattered irregularly	Scattered irregularly	With a regular hind row of large bristles; rest irregular	With one regular hind row of bristles
9. Geographical distribution	Ceylon	Java (Indonesia)	Berra Massidi Is. between Muna Is. and S. E. Celebes (Indonesia)	Ceylon

LAC CULTIVATION ON *FICUS CUNIA* WITH NOTES ON OTHER *FICUS* SPECIES RECORDED AS LAC HOSTS

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Introduction

India is the largest lac-producing country in the world, its annual production being about 80 per cent of the total world production. The *Baisakhi* and *Katki* crops of lac together constitute nearly four-fifths of the country's annual output. The lac insect which produces these crops completes two life cycles in a year. In the plains, the *Katki* crop relates to the life cycle lasting from about June-July to October-November and the *Baisakhi* to the rather long life-cycle, lasting from October-November to June-July, during which period the lac insect passes through the hot summer. The most extensively used hosts for the *Baisakhi* crop are the *dhak* or *palas* (*Butea monosperma* Kuntze, Syn. *B. frondosa* Roxb.) and *ber* or *kul* (*Zizyphus mauritiana* Lam., Syn. *Z. jujuba* Lam.) which become leafless in summer for a certain period. Their lac-covered branches become exposed to the sun and it seems, as if owing mostly to the direct heat and the relative inactivity of the host trees, the lac insects die, the death roll increasing with the severity of the summer. The resin forming the cell becomes soft and the crown of the cell falls in as the dead insect contracts within. The numerous cells constituting the encrustations assume pitted appearance which is characteristic of the heat-affected lac. The waxy filaments which protrude from the spiracular and anal tubercles are no longer to be seen.

During exceptionally hot summers the insect mortality rises very high and results in a poorer crop and an overall shortage of broodlac. The subsequent crop (*Katki*) which depends upon an adequate supply of broodlac from the preceding crop (*Baisakhi*) is also adversely affected. For the same reason certain localities which often experience severe summer suffer from a chronic shortage of broodlac. If, however, lac is cultivated on such hosts as would provide adequate shade to the lac insect by their leaves and thus mitigate the effect of heat, the insect mortality would be greatly reduced and sufficient broodlac obtained in June-July. Several species of *Ficus* and some species of *Albizzia* possess this quality and their use has often been recommended for preservation of *Baisakhi* broodlac.

Preservation of *Baisakhi* Broodlac on *Ficus*

McKee [1876] while discussing the effect of hot and arid climate on the mortality of lac insects in Madhya Pradesh observed that *kusum* (*Schleichera oleosa* Merr., Syn. *S. trijuga* Willd.) and *gular* (*Ficus racemosa* Linn., Syn. *F. glomerata* Roxb.) were " specially adapted for yielding good crops of lac ". Glover [1937] also stated that although the quality of lac produced by a number of *Ficus* species was not good, yet some of them were valuable hosts as they had the capacity of carrying lac in the

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Baisakhi crop to brood in July. He further observed that with *dumber* or *gular* the results were not very satisfactory although small amounts of brood were produced in July ; that *porho* (*F. cunia* Buch.-Ham.) and *pipal* (*F. religiosa* Linn.) successfully preserved the broodlac at Namkum and to a lesser extent this was also done by *pakaur* (*F. lucescens* Blume, Syn. *F. infectoria* Roxb.) and *putkul* (*F. glabella* Blume). In subsequent references* on *porho*, it was stated that good yields of *Baisakhi* and *Katki* crops were obtained from it in 1938 and 1940 respectively. The details of the experiment and other relevant data on the quantity of broodlac applied as well as the yield of crop and the broodlac obtained, were not given and do not appear to have been published since. As the problem relating to preservation of broodlac through hot summer is an important one and as *F. cunia* was reported to yield good broodlac, detailed studies on the use of this species were taken up. Experimental lac-cultivation was carried out at the Namkum plantation and the observations were supplemented by a closer watch on the crops growing on cultivators' trees.

Experiments on *Ficus cunia*

Lac cultivation experiments on *F. cunia* were performed for the *Baisakhi* crop in view of its broodlac preserving quality through the summer. Five and two trees of medium size were under trial respectively for the 1951-52 and 1952-53 crops. The trees had been under infection previously, but in each case before the trees were brought under lac they had at least a year's rest. No special pruning was considered necessary, the earlier cropings serving the purpose of pruning and resulting in fair number of infectable shoots. Further details of the experiments and the data obtained are shown in Table I.

Table I

Results of experimental cultivation of lac on F. cunia

No.	Particulars	*Baisakhi* 1951-52	*Baisakhi* 1952-53
1	Origin of broodlac used	Ex. *ber*	Ex. *palas*
2	Date of infection	22-10-1951	25-10-1952
3	Weight of broodlac applied	5 seers 8 chataks	1 seer 8 chataks
4	Period of infection (Wire-gauze baskets used)	23 days	21 days
5	Weight of *phunki* brood (lac after swarming is over)	3 seers 2 chataks	1 seer 2 chataks
6	Weight of scraped *phunki* brood	1 seer 5½ chataks	4 chataks
7	Date of cropping	26-6-1952	3-6-1953

* *Ann. Rep. Indian Lac Res. Inst.* 1938-39, p. 24 ; 1940-41, p. 21.

TABLE I—(*contd.*)

Results of experimental cultivation of lac on F. cunia

No.	Particulars	*Baisakhi* 1951-52	*Baisakhi* 1952-53
8	Weight of total yield (lac covered sticks) obtained	1 md. 8 seers 13 chataks	10 seers 9 chataks
9	Weight of selected broodlac obtained	37 seers 10 chataks	9 seers 3 chataks
10	Total weight of scraped lac from yield	11 seers 9 chataks	1 seer 13 chataks
11	Percentage of selected broodlac	77·08	88·75
12	Ratio-broodlac used to total yield	1 : 8·87	1 : 7·04
13	Ratio-broodlac used to broodlac obtained	1 : 6·83	1 : 6·25
14	Ratio-scraped lac from brood (*phunki*) to scraped lac from total yield	1 : 8·60	1 : 7·25
15	Cost of broodlac applied (at approximate Rs. 60 per md.)	Rs. 4-8-0	Rs. 2-4-0
16	Income from broodlac obtained (at approximate Rs. 60 per md.)	Rs. 56-7-0	Rs. 14-1-0

Results of the observations taken on certain *porho* trees brought under lac by the cultivators in the village Jate, Khunti sub-division, were in several respects similar to those obtained from the experimental trees. From two medium-sized trees in this village a total yield of 15½ seers of lac with sticks was obtained. Out of this, 13 seers were selected as broodlac which was thus 83·9 per cent of the total yield. In the case of some large-sized trees the yield of lac was nearly 30 seers from a single tree and the proportion of the broodlac was also about the same as stated above.

The villagers freely transferred the broodlac from *porho* on to *palas* and also to *ber* trees. In order to have some further information on the performance of *porho* broodlac on *palas* and *ber* when infected for growing the *Katki* crop, trials were conducted at Namkum during 1951 and 1952. The particulars of the experiments and the results obtained from such trials are given in Table II.

TABLE II

Results of lac cultivation by employing broodlac obtained from F. cunia

No.	Particulars	*Katki* 1951	*Katki* 1952
1	Name and number of host plant	*Ber*, 16	*Palas*, 10
2	Date of infection	3-7-1951	28-6-1952
3	Weight of broodlac used	8 seers 11 chataks	8 seers 1 chatak
4	Period of infection (Wire-gauze baskets used)	26 days	31 days
5	Weight of *phunki*	4 seers 11 chataks	5 seers
6	Date of cropping	20-10-1951	16-10-1952
7	Weight of total yield (lac on stick) obtained.	22 seers	25 seers 8 chataks
8	Weight of selected broodlac	10 seers 5 chataks	17 seers 8 chtaks
9	Percentage of selected broodlac	46·70	68·94
10	Ratio -broodlac used to total yield	1 : 2·53.	1 : 3·16

Attention may specially be drawn to the following points from the observations and results of the above mentioned experiments.

1. As would be seen from Table I, the *ber* as well as the *palas* broodlac could be used on *porho* with equal success for producing a *Baisakhi* crop.

2. The total yield of lac bearing sticks may be seven to eight times or even more than the quantity of broodlac (also with sticks) applied for infecting the trees.

3. The quantity of broodlac obtained from *porho* may be over six times that of broodlac applied on it. This means that for every tree of *porho* under infection in *Baisakhi* crop nearly six trees of the same size of *palas*, *ber* or *porho*, or any other suitable host, could be infected for the next *Katki* crop.

4. The ratio between the scraped lac obtained from the broodlac applied and the scraped lac obtained from the total yield of lac from *porho* was also high (1 : 8·60 ; 1 : 7·25) and clearly indicated the thick nature of encrustations which were as good as any that may be obtained from *palas* or *ber*.

5. From Table II it will be observed that *Baisakhi* broodlac obtained from *porho* proved suitable for both *ber* and *palas* for *Katki* crops. The results obtained were comparable to those where *ber* or *palas* broodlac was applied.

APPLICATION OF RESULTS

It is obvious from the foregoing account that *porho* if brought under lac would not only yield satisfactory quantity of broodlac but also that of scraped lac or the sticklac of commerce.

The arrangements under which this species may be utilized to the best advantage of the cultivator would largely depend upon the kind and number of trees at his disposal and other local conditions. *Porho* could be brought under lac alone because it is capable of yielding broodlac from both *Baisakhi* and *Katki* crops, and would in fact produce surplus broodlac. It would, therefore, be more profitable if it could be used in conjunction with other hosts such as *ber* and *palas*. The plan of work may be briefly described as follows :

The *porho* trees should be divided into two coupes. Each coupe should have an equal number of trees (of equal size) and should be brought under lac every alternate year, so that after bearing lac crop for a year the trees get a year's time to recoupe from the drain on it due to insect attack and to the cutting down of its branches at the time of cropping.

If the tree is being brought under lac for the first time, it would be necessary to prune it sometime in April. By October-November when the infection for the next *Baisakhi* crop is due, sufficient number of infectable shoots would become available. These should be neither lightly nor heavily infected at this time. If, however, the tree has already been under cultivation and is being cropped carefully, cropping will serve the purpose of pruning.

Baisakhi crop matures sometime in June-July, depending on the place and season, and is not to be cropped immature (*ari*). The right time for cropping should be closely watched with a view to obtaining the best quality and maximum quantity of broodlac because it will always be more profitable to sell broodlac than to sell scraped lac. Brood should not be cut much earlier or later than the time of emergence of lac larvae. The visual method of determining the right time for cropping broodlac is quite helpful. As the time of emergence approaches, one has to look for the yellow spot that appears on the lac cell near the anal pore. The yellow spot appears as a result of the contraction of the female body inside the cell ; the body contracts so that a portion of the cell may be vacated for depositing the eggs from which the young larvae hatch. The lac can be safely cropped when the yellow spot occupies nearly two-fifths to four-fifths of the crown or top area of the cell containing a healthy female. That the latter is healthy and unparasitized could be ascertained by breaking open a cell ; a healthy cell contains a crimson female with semifluid granular body while a parasitized cell will contain whitish grubs or pupae of parasites. The larval emergence will normally commence within about five days from the time the fore-mentioned state of yellow spot is reached.

At the time of *Baisakhi* cropping, care should be taken that, as far as practicable, the branches which do not carry lac but are infectable are not cut off the tree as these might be utilized for the succeeding *Katki* crop. Branches covered heavily with lac incrustations should be cut while those which bear sparse settlements should be left uncut on the tree to serve as brood for infecting the remainder of the tree for the

Katki crop. In case it is felt that their quantity or number will not suffice, a few of the more heavily infected branches or parts thereof may also be left on the tree for the larvae to swarm *in situ*. The *Katki* crop would be ready for cropping in October-November and should be *cropped completely* at this time. As this cropping is to serve the purpose of pruning also in the case of this species, same care should be exercised in conducting this operation as has been advised for the pruning operation. The broodlac obtained from this coupe is utilized for infecting the second of the two *porho* coupes. The second coupe receives the same treatment as the first one. The two-coupe system is more or less practised for this species by most cultivators in the neighbourhood of Ranchi and the system seems to be working quite well.

As has been observed earlier, the quantity of surplus *Baisakhi* broodlac obtained from one *porho* tree would be sufficient to infect five to six trees of *palas*, *ber*, etc. (of about the same size) for the *Katki* crop. A cultivator may infect as many trees for the *Katki* crop as possible and sell the surplus broodlac. The *Katki* crop from *palas* or *ber* may also yield in October-November two to three times the quantity of broodlac applied. Since there is very little insect mortality in the *Katki* crop the entire surplus crop may perhaps be sold as broodlac in the market in October-November when there is considerable demand for it. There are two reasons for this demand ; firstly the number of trees under *Katki* crop is generally much less than that under *Baisakhi* owing to shortage of broodlac ; secondly owing to demand in the trade and to other causes, the villagers generally prefer to infect their *ber* trees in October-November for the *Baisakhi* crop which they cut *ari* in May. Since *ber* cannot efficiently preserve broodlac during hot summer, a cultivator has to arrange for broodlac from other hosts. He generally meets his broodlac requirement for infecting *ber* partly from his *palas* and other similar trees and partly from the purchased broodlac. If the abovementioned scheme is followed, an owner of *porho* trees can easily play the profitable role of a broodlac supplier.

A Review of Lac Cultivation on other Species of *Ficus*

There are some 24 species of *Ficus* recorded as lac-hosts in the Indian region. Earlier literature on lac is rather scattered and generally inaccessible to field workers who otherwise may have excellent opportunities of adding to our knowledge of lac cultivation by further observations and trials. It is hoped that the notes given below would be found useful by those who would like to try lac cultivation especially with a view to preserving broodlac from the *Baisakhi* crop.

In reviewing the subject only important references have been cited ; those containing already recorded information have been omitted. The specific names of the lac insects employed in the notes are the same as given by various authors in their respective publications but the generic name *Laccifer* has been used in place of *Tachardia*, *Lakshadia*, etc. which are now redundant.

1. Ficus alternans Wall ?

Stebbing [1910] recorded ' *Ficus alternarine* ' as a lac host in Assam. So far as the author of this article is concerned he gathers that there is no species of *Ficus* by that name. Presumably Stebbing meant *F. alternans* Wall. No subsequent writer on lac hosts seems to have referred to the name mentioned by him.

2. Ficus altissima Blume

(Syn. *Ficus laccifera* Roxb. Vern. *Bars, domaru, kathali bat*)

This species is utilized for lac cultivation in Assam, particularly in Sylhet [Stebbing, 1910] and Nowgong [Glover, 1936] . Basu [1900] reported that it was able to carry ' lac for three or four years in succession ' after which it required rest. He further stated that some trees had been reported to produce lac for ten or twelve years without rest and that a good size tree yielded from 30 seers to two maunds of sticklac. Watt [1901] stated that the lac reared on *arhar* plants in Assam could be put on to *F. altissima* although the quality of lac grown on *arhar* was the best.

This species is found in the Himalayas from Nepal to Bhutan and Assam and also occurs in the plains and lower hills of Deccan where it may be tried as a host.

3. Ficus arnottiana Miq.

Mahadihassan [1936] while recording *Laccifer mysorensis* (Mahad.) on this host at Bangalore writes, " Rangaswamy found the tree he infected produce patchy encrustations indicative of high death rate. He grew only two generations ".

Although distributed in Bihar and Orissa also, this species is epiphytic on trees and rocks and would, therefore, be of little value as a lac host.

4. Ficus bengalensis Linn.

(Syn. *Ficus indica* Roxb. The banyan tree. Vern. *barh, barghat, bargad; gitting* - Assam)

Apparently three species of lac insects have been recorded from this host.

(1) *Laccifer communis* (Mahad.) from Mysore and Hyderabad [Mahadihassan, 1936].

(2) *Laccifer fici* (Green) was recorded from Monghyr (Bihar) by Chamberlin [1923]. Type slide* of this species in the Green Collection (now in the British Museum (N. H.)) bears the following note : " Watt gives the locality as Monghyr, collector E. H. Walsh but says that the host was *Ficus religiosa*, the peepal ". Another slide of it bears the label " on *Ficus bengalensis* from India, Coll. G. Watt." Note on this says, "Watt does not mention *F. bengalensis* but *F. religiosa*." There is, however, another slide of the species in the Green collection which bears the label : " on *Ficus bengalensis*, Kangra District, India, collector J. H. Burkhill ".

(3) *Laccifer lacca* [Kerr, 1781] which is the most common Indian species has been recorded on this host from Rajputana, the Punjab; Uttar Pradesh (U. P.), Madhya Pradesh (C. P.), Bihar, Bengal and Assam in India and from Shan States and Chindwin Circle in Burma by various authors [Kerr, *loc. cit.* ; Watt, 1901 ; Stebbing, 1910 ; Norris, 1932 ; Glover, 1937]. In Garro Hills, Assam, this host carries the *Rangeeni* strain of lac and according to Glover it is one of the hosts utilized for growing *Katki*

* This information on the Green Collection was very kindly supplied to me by Dr W. J. Hall, Director, Commonwealth Institute of Entomology, London, who is himself an authority on Coccidoidea.

crop from the *Baisakhi* broodlac obtained from *arhar* (*Cajanus cajan*). Norris does not regard it as a rare host in the Federated Shan States and Stebbing considers it to be one of " the most important and valuable lac-yielding trees ".

A huge banyan tree was observed by the writer at Sonthi near Karnal (Punjab) to carry considerable lac settlement and was a constant source of broodlac in spite of the hot and arid climate of the place. A few yellow cells were also observed on this tree and it is possible that the tree carried both *L. lacca* and *L. fici* species. The banyan trees are planted throughout India and could be extensively utilized for preservation of *Baisakhi* broodlac. In hot areas where *palas*, *ber* or *ghont* (*Zizyphus xylopyra*) are being used for growing lac, it would be advisable to plant this and other suitable *Ficus* species in between the fore-mentioned trees. In the *palas* lac orchard at Kundri—a hot and arid place in Palamau district, Chota Nagpur—the couple of banyan trees present are highly prized as an additional source of broodlac in July.

5. F. bengalensis Var. krishnae C. DC.

Mahadihassan [1936] produced lac on this host by artificially inoculating *L. mysorensis* (Mahad.) on it in Bangalore. No further record is known from this host.

6. Ficus carica Linn.

(The fig tree. Vern. *angir*)

Watt [1901] recorded it as a lac host in the Punjab. In Bangalore, Mahadihassan [1936] recorded *L. communis* (Mahad.) on the fig tree. Lately lac specimens of the crimson and yellow varieties were obtained from this species growing in New Delhi. Since the plants are grown for their fruits there seems to be no justification for putting them under lac.

7. Ficus comosa Roxb.

(Vern. *Juri pakhari* Assam)

This species has been recorded as a lac host in Assam by Watt [1901] where according to him it is able to carry successfully broodlac from *arhar*. Mahadihassan [1936] reared *L. communis* (Mahad.) on it in the Botanical Garden, Bangalore.

In Bihar this host species occurs in Champaran, Forests of Ranagar and Bettiah, Santhal Parganas, Singbhum, Manbhum and Hazaribagh and it may be worth while trying it as an additional source of lac in the State.

8. Ficus cotoneaefolia Vahl.

(Syn. *Ficus mysorensis* Heyne)

Imms and Chatterji [1915] state that small quantity of lac was collected from this host in Kollegal, Madras. Mahadihassan [1923] described his *Laccifer communis* from this host in Mysore and stated [1936] it to be "the most common host of this species in Mysore". This host is distributed in the forests at the base of the Himalayas from Sikkim eastward, the Deccan Peninsula and in Ceylon. It may be looked for as a lac host in North-East India.

9. Ficus cunia Buch. Ham.

(Syn. *Ficus conglomerata* Roxb. Vern. *Porho, podoh*; *ari*—Munda; *thadut*-Burma)

Originally reported to carry lac in the Punjab and Bengal [Watt, 1901; Stebbing, 1910], it is frequently utilized for lac cultivation in various parts of Chota Nagpur and in Khasi, Mikir and Garo Hills in Assam. It is also a host in the Shan States and Maymyo Division in Burma [Glover, 1937].

In the light of the experiments reported earlier in this paper this should prove to be useful host for carrying broodlac through the summer and for a satisfactory production of sticklac. Since it is distributed throughout the greater part of India (common particularly on the sides of ravines) it should be given trials in other parts of the country also.

10. Ficus cunninghami Miq.

Mahadihassan [1936] makes some five records of cultivating *R. mysorensis* (Mahad.) on this host in Bangalore on the strength of artificial infection.

11. Ficus elastica Roxb.

(The India-rubber tree)

The following two species of lac insects are recorded on this host.

(1) *Laccifer ebrachiata* [Chamberlin, 1925] from Bangalore.

(2) *Laccifer lacca* (Kerr) from Assam [Watt, 1901] and Rajputana [Chamberlin, 1923].

12. Ficus glabella Blume

(Vern. *Putkal*)

The *Rangeeni* strain of *Laccifer lacca* is cultivated on it in various parts of Chota Nagpur. According to Glover [1937] the species is capable of carrying the lac in the *Baisakhi* crop to brood in July though not as successfully as *porho* (*F. cunia*) and *pipal* (*F. religiosa*) but equal to *pakaur* (*F. infectoria* Roxb.) and better than *dumber* (*F. glomerata* Roxb.).

13. Ficus hispida Linn.

(Syn. *Ficus oppositifolia* Roxb. Vern. *Dumar*)

Norris [1932] reported it to be a lac host from the Shan States, Burma. In India this the species is distributed in the outer Himalayas from the Chenub eastward, Bengal, Central and South India. In Chota Nagpur it retains foliage during the greater parts of summer and may be tried for lac cultivation in this and other parts of the country.

14. Ficus lucescens Blume

(Syn. *Ficus infectoria* Roxb. Vern. *Pakaur, pakri*)

It has been very frequently mentioned as a host for the lac insect and has been recorded as such from Uttar Pradesh, Madhya Pradesh, Bihar, Bengal and Assam [Stebbing, 1910], East Khandesh, Bombay State [Imms and Chatterji, 1915], and

from the Shan States and Maymyo Division in Burma [Norris, 1932 ; Glover, 1937]. In his account of the rearing of lac insect in Rangpur district, written in 1809 (published in *Asiatic Journal*, 1826, p. 50) Buchanan—Hamilton refers to this host in the following words. "The best lac is produced on the *pakur*. Branches of this tree are planted in the rainy season and in three years are of a size fit for receiving the insect, which is applied between the 15th of September and the 13th of November. In a year they have spread over all the small branches and these are afterwards cut once or twice a year for about 25 years. A large tree will give two maunds. The smallest give about 1/16 of that quantity".

The species is stated to have several races, "one of which is a good *Baisakhi* host and another of which though a poor *Baisakhi* host is quite valuable for the *Katki* crop" [Glover, 1937]. Good results are stated to have been obtained at Namkum by infecting *palas* brood on it for the *Baisakhi* crop and by infecting the latter broodlac on *khair* (*Accacia catechu*) for the *Katki* crop (*Ann. Rep. I.L.R.I.*, 1937-38 ; 1940-41).

In Chota Nagpur it seems to be able to serve as a host for both the *Kusumi* and *Rangeeni* strains of lac. In localities where *Kusumi* strain is extensively cultivated, lucescens is infected with this strain in times when the cultivators have enough spare *Kusumi* broodlac. They would usually do this for the *Aghani* crop (June-July to January-February) and obtain as heavy encrustations of lac as may be normally had from *kusum* itself. *Jethwi* crop (January-February to June-July) is usually not obtained from this host apparently because the trees become leafless in early summer. It is sometime said that if the *Kusumi* strain is allowed to develop on this host for a few generations it would tend to emerge earlier than the usual time. Preliminary observations on this point made at Namkum do not support this idea but a thorough investigation would be necessary in order to dispel this belief finally.

The species is widely distributed in India, being found in the Suleman Ranges, outer Himalayas, plains and hills of India (Bengal, Bihar, Central India) and the forests of Western Coast. As it appears to be a host of potential importance experimental lac cultivation on it in different parts of the country is likely to prove very fruitful.

15. Ficus nervosa Roth.

The following two species of the lac insects have been recorded on this host.

(1) *Laccifer albizziae* (Green) in Ceylon [Green, 1910].

(2) *Laccifer lacca* (Kerr) in Burma [Stebbing, 1910] from the Shan States, Maymyo Division and the Northern Circle [Glover, 1937].

In India the host species is distributed in the Sikkim and Bhutan Himalayas, the Khasi Hills, Assam and it also occurs rather sparsely in Chota Nagpur (Singhbhum District), Santhal Parganas, Orissa and the Deccan Peninsula and deserves to be investigated further.

16. Ficus obtusifolia Roxb.

Laccifer lacca (Kerr) is recorded by Stebbing [1910] from this host in Burma. According to Norris [1932] this is not a rare lac host in the Shan States. Distributed in North-East India (Sikkim to Manipur, Chittagong, etc.) this host may be of local interest only.

17. Ficus palmata Forssk.

(Vern. *Pheru anjiri* ; *Phagura*-Punjab)

Recorded as a lac host by Watt [1901] and Stebbing [1910] in the Punjab. It is found in the Suleman and Salt Ranges and in the Outer Himalayas of the Punjab, eastward to Oudh and Nepal, ascending up to 7,000 ft. and may be of limited interest only in certain of these tracts.

18. Ficus racemosa Linn.

(Syn. *Ficus glomerata* Roxb. Vern. *Dumber*, *gular*)

As stated earlier, McKee [1876] seems to have been the first to record the value of this host as a *Baisakhi* brood preserver in the hot areas of Madhya Pradesh (C.P). This species has been reported as a lac-host from Chota Nagpur, West Bengal, the Punjab, Rajputana, Uttar Pradesh and Madhya Pradesh [Watt, 1901 ; Stebbing, 1910 ; Glover, 1937]. It was reported as a host in the Shan States [Norris, 1932] and Maymyo Division in Burma. Glover states that in some districts (of Bihar) it is a good *Baisakhi* host whereas in others it is a failure during this crop. Negi [1946] recommends its use for growing *Baisakhi* crop in hot areas. However, no data have been given by these authors in support of their conclusions or recommendations.

L. communis (Mahad.) has been recorded on it in Bangalore and Hyderabad Deccan by Mahadihassan [1936].

The species is distributed in the Salt Range, Rajputana, along the Sub-Himalayan tracts to Bengal, Central and South India, Assam and Burma and deserves to be given critical trials.

19. Ficus religiosa Linn.

(Vern. *Pipal*, *asvatha*-Sanskrit)

The following three species of lac insects have been recorded from this host tree ;

(1) *Laccifer communis* [Mahodihassan, 1923] from Hyderabad Deccan.

(2) *Laccifer fici* [Green, 1903] recorded on *F. religiosa* from Monghyr, North Bihar. Recently some further samples collected from the same locality also showed the crimson and yellow varieties.

(3) *Laccifer lacca* (Kerr). This is the commonest species of lac insect in India. it was first described by Kerr [1781] under the name *Coccus lacca* from specimens "on the *pipal*, the banian and the *palas*" from Bengal (then including parts of Bihar, etc.). Since then many further records have been made of *F. religiosa* as a lac host

from various parts of India. This tree was one of the five hosts mentioned in Buchanum-Hamilton's account, already referred to on page 12, on lac cultivation in Rangpur district. Manson (1882, p. 274) stated that in the district of Beerbhum it was a principal lac host. In 1896, the Director of Land Records and Agriculture, Assam [*vide* Watt, 1901], reported that *Ficus religiosa* was one of the host trees on which broodlac from *arhar* (*Cajanus cajan*) was reared in Assam. It was recorded as one of the four chief lac-yielding trees in Kaira and Panch Mahals in Bombay (*Bombay Gazetter*, Vol. III, 1879, p. 249). In the later part of the 18th and beginning of the 19th century it was recorded by various authors from the Punjab, Uttar Pradesh (Western and Eastern Forest Circles), Madhya Pradesh (Northern Forest Circle and Berar), West Bengal, Bombay (Khandesh, South Thana, Kolaba and Nasik) and Travancore [Stebbing 1910; Imms and Chatterji, 1915]. In the Shan States and the Maymyo Division, in Burma it was recorded as a host of greater importance [Norris, 1932; Glover, 1937]. The *pipal* trees are extensively cultivated in most States of India and also in Burma and may be utilized for brood preservation.

20. Ficus retusa Linn.

(Syn. *F. benjamina* Linn.)

Mahadhihassan [1936] who reared *L. Communis* (Mahd.) on this species at Bangalore States: "Three records, all from Botanic Garden". This host is widely distributed throughout the Sub-Himalayan tract from the Siwaliks near Dehra Dun eastward to Assam, Chota Nagpur and the Indian Peninsula and may, if tried for lac cultivation, prove to be of more than local interest.

21. Ficus roxburghii Wall. ex Roxb.

(Syn. *Ficus macrophylla* Roxb. non Kunth & Bouch. Vern. *Timal*-Burma)

Golver [1937] records it as a host of the lac insect, *lacca*, in the Shan States and Maymyo Division, Burma. As the tree is indiginous in the Sub-Himalayas and outer Himalayas from the Indus eastward to Chota Nagpur, Orissa, Bengal and Assam, it would be worthwhile trying this host by artificial infection in India.

22. Ficus rumphii Wall. ex Roxb.

(Syn. *Ficus cordifolia* Roxb. non Bluma. Vern. *Jhuri, Jariahat, pakori ; prap*—Assam)

It is an important host in Assam. According to Watt [1901] the broodlac from *arhar* (*Cajanus cajan* Druce) is put on this species in Assam. Glover [1937] states that in the Garo Hills this practice is followed for obtaining the *Katki* crop from *rumphii*. Stebbing [1910] further records this species from Satara Division, Bombay. In Burma, lac is collected from it in Mandalay District and the neighbouring Hsibaw State [Watt, *loc. cit.*].

Found also on the dry, lower slopes of the mountains of the Punjab and in Chota Nagpur (Singhbhum, Hazaribagh, etc.), Bengal and the Indian Peninsula, this host may be more extensively tried in various parts of India.

23. Ficus tjakela Miq.

(Vern. *Pilkhan*—Punjab ; *pakhar*—Madhya Pradesh)

Watt [1901] and Stebbing [1910] recorded it as a lac host in the Punjab and Madhya Pradesh (C.P.). In Karnal District, the Punjab, a '*pilkhan*' tree was recently noticed to carry lac successfully through the summer to brood in July.

24. Ficus tjiala Miq.

(Syn. *Ficus tsiela* Roxb.)

Glover [1937] recorded it as a lac host in the Bombay State. The species is stated to be of frequent occurrence in Madhya Pradesh where it might be experimented upon with reference to its brood preserving quality.

ACKNOWLEDGMENT

The author wishes to record his appreciation of the kindness with which Sir Edward Salisbury of the Kew arranged to get the names of certain host plants corrected. Dr W. J. Hall, C.M.G., Director, Commonwealth Institute of Entomology, London, was also extremely kind in supplying information on the type and other material of lac insects in the British Museum (N. H.). The author is also grateful to Dr S. L. Hora, Director of the Survey, for the interest shown by him and the encouragement given. Thanks are also due to Shri Purokayastha, Arboricultural Assistant, Indian Lac Research Institute, Namkum, for assistance rendered in the experimental work.

SUMMARY

A serious obstacle in the way of increasing lac production is the almost chronic shortage of broodlac from the *Baisakhi* crop (October-November to June-July) in the plains where *palas* (*Butes monosperma*) and *ber* or *kul* (*Zizyphus mauritiana*) are the principal hosts. As these trees become leafless and relatively inactive for a part of the summer, large settlements of lac insects die according to severity of the heat. The smaller number of insects that survive and constitute the broodlac seriously limit the production of the succeeding *Katki* crop.

Several *Ficus* and *Albizzia* species are known to provide shade and preserve broodlac through the hot summer months. Experiments performed on *porho* (*F. cunia*) at Namkum during three years (1951-53) showed that besides giving an overall satisfactory yield, each *porho* tree was able to preserve broodlac sufficient for infecting six trees of *palas* or *ber* of about the same size. A suitable plan for utilizing *porho* trees is given.

A review of the available information on lac cultivation on 24 kinds of *Ficus* plants together with short notes on their distribution are given in the hope that further trials may be made on these by forest officers and others who may have opportunities of doing so.

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REVIEWS

ENGINEERING FOR AGRICULTURAL DRAINAGE

By Roe and Ayres

(Published by McGraw Hill International Corporation, New York, 1954, pp. 501)

THIS is the latest book published in the U.S.A. on drainage of agricultural land. The authors are already well-known to the students in the U.S. land grant colleges of agriculture. Mr. H. B. Roe is the author of a book entitled "Moisture requirements in agriculture". Prof. Q. C. Ayres is the author of another text-book, "Land drainage and reclamation". As the name itself indicates, the present book by these two authors deals with the engineering aspects of land drainage. In this new text-book, a special chapter "Drain tiles and standards of quality" has been added by Mr. D. G. Miller. This practice of utilising the specialised knowledge of individuals in the publication of text-books seems to be new in the U.S.A. and has to be commended.

As stated earlier, Prof. Ayres is the author of a well-known text-book on lan drainage in the U.S.A. and in this new publication, some parts from the origina book have been utilised. Although there have been some publications in India in the field of irrigation, there are not many in the field of agricultural drainage. There is only one bulletin published in India on methods of agricultural drainage by an agricultural officer of Mysore State. This Indian publication is not the result of any work done in India, but is a compilation in a simple manner of some of the Western practices of drainage which can be adopted in India. That there are no publications on this subject in India does not mean that the problem does not exist. Irrigation is practised in India for centuries and drainage is a problem, sometimes associated with irrigation. Much scientific work has not been done in India in the past on drainage of agricultural land. To quote only few instances, the rapid silting of irrigation tanks in South India is related to imperfect surface-drainage practices of agricultural land. The salinity and high water table in the irrigated areas of India is connected with want of proper sub-surface drainage.

As usual in books of this kind, the first three chapters deal with soils and their water properties. The fourth chapter, "Rainfall and run-off", indicates the latest methods adopted in the U.S.A. for calculation of run-off. The methods of graphing rainfall intensities should be of interest to weather experts and engineers. Chapters five to eight deal with the design and construction of surface ditches. The use of machinery for construction of open ditches, canals, etc. and the mechanical methods of maintenance of channels etc. should be of interest to Irrigation Engineers. While motor-graders, dredges and dragline excavators are available in India, their use for making surface wells, channels or canals does not seem to be known. Information on this can be found in chapter 8. Chapter 9 deals with the use of explosives in ditch construction and ditch maintenance and this aspect needs an examination under Indian conditions. The control of weeds and vegetation in irrigation channels by use of chemicals has also been mentioned.

Chapters 10, 11 and 12 refer to design and construction of under-drains or what are usually known as tile drains. There does not seem to be any tile drain installation in India so far, but some years ago, the use of rubble stone and rough timber for sub-surface drainage was adopted in Bombay State. Chapter 13 which deals with " Drainage of irrigated lands " should be of special interest to engineers and administrators in the large river valley projects of India. It would be better if considerations of drainage are simultaneously taken along with the irrigation projects. The effects of poor drainage, making irrigated lands less productive, have begun to be felt in some States as Mysore and the Punjab. Chapters 14, 15 and 16, which refer to peat and muck lands, cost of drainage and drainage laws, are not of interest under Indian conditions.

This text-book should be of use to students of Civil Engineering and Irrigation in the Engineering Colleges and Schools of India. Some chapters are of interest to soil scientists and agricultural officers. Some facts as " use of explosives in ditch making ", " control of vegetation by chemical methods " and " drainage of irrigated land " will be of interest to administrators and financiers who are interested in the development of agriculture and irrigation in India. The printing, illustrations and graphs are of high standard found in recent American publications. (R.V.R.)

THE PESTS OF FRUITS AND HOPS

By A. M. Massee

(Published by Crosby Lockwood & Son, Ltd., London , 1954, pp. XVI+325 Price 25 Shillings or Rs. 16 approximately)

THIS is the third and entirely revised edition of a book published first in 1937 ; the second edition of which appeared in 1945 and the second revised edition in 1946. In this latest edition, the author has been assisted by three other specialists, G.H.L. Dicker, R.P. Tew and Geoffrey Fletcher. Prof. V.B. Wigglesworth, the well-known insect physiologist, has contributed a foreword commending the book.

The book is divided into fifteen chapters, followed at the end by scientific and general indices. The first twelve chapters deal with pests of various fruits and hops grown in the United Kingdom and the last three deal with beneficial and harmless species of insects, insecticides and spraying machinery. Apple, cherry, currant, gooseberry, pear, plum and damson, raspberry, strawberry and hop have a chapter each to themselves. Some other fruits dealt with in the remaining three chapters include various berries, nuts and peach, appricot and nectarine. At the beginning of each chapter, a list is given of the insect and other pests that infest the fruit tree or trees, and those which are considered most important are indicated by asterisk marks. This is followed by brief descriptions of the pests, notes on their life cycles and suggestions for control measures. Both the common English and the scientific names of the insects are given.

Most of the control measures recommended involve spraying, dusting or poison-baiting. The insecticides recommended for use are not only such modern insecticides as DDT, BHC, Schradan, parathion and TEPP, but also the older ones like

Paris Green, lead arsenate, sodium flousilicate, nicotine sulphate, lime, sulphur and derris. Mention may be made of the recommendation to control a caterpillar pest (*Triphoena pronuba* L.) of strawberry by the application of 5 per cent DDT dust at the rate of 2½ to 3 cwt. per acre. To us in India, accustomed to dusting even such fairly thick crops as sugarcane, cotton or paddy with BHC or DDT at the rate of only about 20 to 50 lb. per acre, the dosage recommended must appear excessive, costing as it may be, Rs. 100 or more per acre for the insecticide alone.

In chapter XIII, 60 insect species, predaceous or parasitic on insect pests of fruits and hops are listed by their common and scientific names, classified under different families and orders. Thereafter, some details about the life cycles, habits and performances of each are appended. The well-known parasite, *Aphelinus mali* Hald., of wooly aphis is considered to have proved very successful in many orchards during the past ten years, though its performance earlier was considered to be of very doubtful utility. In India, this very parasite has been extensively tried in the Punjab (undivided) and Uttar Pradesh and while it has been claimed to be successful in the former, it has failed to do much good in the latter. Chapter XIV dealing with insecticides is likely to interest the specialist more than the fruit grower for whom the book as a whole is primarily intended. The chapter on spraying machinery deals largely with three types of spraying, namely, high volume, medium volume and low volume and also discusses the advantages and disadvantages of automatic spraying. In a brief reference to aeroplanes and helicopters, the opinion is expressed that the former are unlikely ever to prove a practicable proposition so far as spraying of fruits and hops in the U.K. is concerned.

In the preface to the first and second editions of the book, the author states that " the question of plant immunity is being studied more closely than ever before and even now there are signs that in the dim future it may be possible to relegate the spraying machine to an honourable retirement ". This was written in 1936 and even after a lapse of 18 years, the ' dim future ' is nowhere in sight. In India at least, in spite of considerable work on the resistance of plants to pest attacks, there is not a single pest problem which has so far been solved satisfactorily by this method.

The book not only gives clear and concise information on orchard pests and the methods of their control, but incidentally indicates their present relative importance in the United Kingdom. It is interesting to note that plant protection measures, which are now commonly employed in practically all orchards of the country, have effectively altered the economic status of some pests. For example, the apple sucker, which used to be a very destructive pest of apple, is now not of much consequence.

The book contains 33 plates of illustrations, including one in colour, and is a very useful addition to the growing literature on pest control. Several of the pests dealt with in it or those closely allied to them occur as pests in India also, and plant protection workers in this country can study the book with great profit. (K.B.L.)

BIBLIOGRAPHY OF SOIL SCIENCE, FERTILIZERS AND GENERAL AGRONOMY, 1950-53

(Published by the Commonwealth Bureau of Soil Science, Harpenden, England, 1954)

THE importance attached to problems connected with soil science and agronomy can be seen from the number of scientific publications dealing with the various branches of this subject, which are continuously increasing in recent years. Besides having to cope with these increasing numbers in ones own subject of specialisation, one has to keep abreast of advances in many of the allied subjects with which soil science is intimately connected and which are distributed in diverse journals, many of which are not always accessible. The task of the soil scientist is, therefore, becoming increasingly difficult. The publication of this seventh volume of Bibliography on Soil Science, Fertilizers and General Agronomy for 1950-53 by the Commonwealth Bureau of Soil Science has, as in the past, come to be of invaluable help to research workers in these fields. Besides having all references for the period of four years on any subject collected at one place and on related subjects in their natural sequence in the decimal system of indexing subjects, even regular subscribers to ' Soils and Fertilizers ', which is also published regularly by the Commonwealth Bureau of Soil Science, will find this Bibliography containing references that can not be found in the above abstracting journal.

The Bibliography deals with a very large number of subjects related to soil science, such as sociology, astronomy, physics, chemistry, geology, biology, botany, zoology, pathology, animal diseases, engineering, agriculture, soils, cultural operations, agricultural engineering, fertilizers and manures, plant diseases and protection, cultivated crops, orchards, fruit, forestry, vegetables, ornamental horticulture, livestock and products and miscellaneous subjects like carbon black, charcoal, yeast, molasses, mineral oil, resins, leather, wool, aerial photography, archaeology and history.

The use of the extensive subject and author indices provided at the end of the volume has made the publication particularly useful. This volume is indispensible for every institute and library connected with agriculture or soil science (S.P.R.)

MGIPC—M—140 AR/54—6-6-55—1,000.

ERRATA

(The Indian Journal of Agricultural Science, Vol. XXV, Part I, March 1955)

Page	*Line*	*For*	*Read*
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The Editorial Board in its work of examining papers received for publication is assisted in an honorary capacity by a large number of scientists working in various parts of India.

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Articles intended for *The Indian Journal of Agricultural Science* should be accompanied by short popular abstracts of about 330 words each.

In the case of botanical and zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

Reference to literature, arranged alphabetically according to authors' names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets; when the author's name occurs in the text, the year of publication only need be given in brackets. If the reference is made to several articles published by one author in a single year these should be numbered in sequence and the number quoted after year both in the text and the collected references.

If a paper has not been seen in original it is safe to state 'original not seen'. Sources of information should be specifically acknowledged.

As the *format* of the journal has been standardized, the size adopted being crown-quarto (about 7½ in. × 9⅝ in. cut) no text figure, when printed, should exceed 4½ in. × 5 in. Figures for plates should be so planned as to fill a crown-quarto page, the maximum space available for figures being 5½ in. × 8 in. exclusive of that for letter press printing.

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